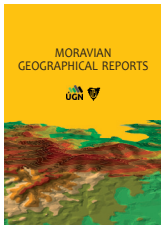

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Habits over space: Determinants of online shopping in a polycentric metropolitan region

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Abstract

The COVID-19 pandemic accelerated the adoption of online shopping, making it an integral part of consumer behaviour. This surge in e-commerce adoption has potential implications for transport behaviour, spatial patterns of transport flows, and modifications to existing transport infrastructure. This paper aims to explain the spatial patterns of online shopping behaviour and its relationship to in-store shopping in the metropolitan region of Ostrava, a medium-sized polycentric agglomeration in the Czech Republic. The innovation-diffusion hypothesis was tested, which posits higher e-commerce adoption in urban cores, and the efficiency hypothesis, suggesting that e-commerce reduces the need for shopping-related travel. The research draws on survey data from 468 respondents to examine the effects of spatial, sociodemographic, and attitudinal variables on the frequency of online shopping. General linear models were employed to test both current differences in the frequency of online shopping behaviour and changes during the COVID-19 pandemic. Neither the innovation-diffusion hypothesis nor the efficiency hypothesis was supported. The frequency of online shopping showed relatively minor intra-metropolitan differences, with no systematic effects of urban form, centrality or accessibility. Lifestyle habits (specifically, time spent online) emerged as the most significant predictor of online shopping behaviour. The findings revealed no significant substitution or complementary effects between online and in-store shopping, suggesting a neutral relationship. These results highlight the primacy of individual lifestyle and e-commerce adoption over spatial and sociodemographic factors in shaping patterns of shopping behaviour.

Keywords: Online shopping, in-store shopping, accessibility, metropolitan region, spatial patterns

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1. Introduction

The intensity of e-commerce has increased substantially during last two decades (Cao et al., 2013; Diaz-Gutierrez et al., 2023) and has been further exacerbated by the COVID-19 pandemic (Young et al., 2022). E-commerce can substantially change urban transportation behaviour, volume, intensity and spatial patterns of transport flows and even modify the existing transport infrastructure (Shi et al., 2019).

Additionally, there have been concerns that the growth of e-commerce might amplify the challenges already posed by shopping malls to urban centres in retaining retail activity, further diminishing their vitality and weakening their role as vibrant social and economic hubs (e.g., Slach et al., 2020).

Online shopping affects the frequency and intensity of in-store shopping (Farag et al., 2006a; Farag et al., 2006b; Farag et al., 2007; Cao et al., 2013; Le et al., 2022; Arranz-López et al., 2023) in several possible ways. It may generate additional shopping travel (complementarity), lead to the replacement and reduction of the in-store shopping (substitution) or shifts in the geography, duration of shopping and types of shops visited (modification). There may also be no direct effect on household shopping behaviour-neutrality (e.g., Farag et al., 2006a; Mokhtarian, 1990; Salomon, 1985) or the rebound effect (Masanet & Matthews, 2010): rising travel demand resulting from the efficiency of online shopping that allows for additional consumption of the households (Le et al., 2022). The type and magnitude of these effects vary substantially across different cities and also at the intra-urban level, responding to the urban morphology and accessibility.

Concerning the spatial diffusion of e-commerce acceptance and intra-metropolitan geographies of the online shopping behaviour, Anderson et al. (2003) proposed two opposite canonical hypotheses. The innovation-diffusion hypothesis expects the spread of online shopping behaviour from the urban cores towards remote hinterlands as a consequence of hierarchical spatial innovation diffusion (Hägerstrand, 1967). The efficiency hypothesis, on the other hand, states that higher intensity of online shopping occurs in remote areas as a substitute for less accessible in-store shopping opportunities.

The key research question of this paper is whether, how and to what extent does the intensity of online shopping affect the frequency of in-store shopping behaviour in Ostrava, a medium-sized polycentric industrial city in the Czech Republic (Slach et al., 2019). Considering the relatively weak position of the urban core, strong competition from secondary commercial and retail subcentres, good accessibility of shops in the hinterlands, and high penetration of the pickup points even in small municipalities of the metropolitan area, it seems unlikely that either of the above-mentioned hypotheses will be empirically supported. Ostrava thus represents a least-likely

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case (Gerring & Cojocaru, 2016) for the testing of the innovation-diffusion and the efficiency hypothesis concerning the effects of online shopping on the frequency of in-store shopping.

In addition to the testing of these two above-mentioned hypotheses, the analysis is organised around three partial research objectives. Firstly, to determine whether the effects of online shopping on in-store shopping in Ostrava correspond with the categories of generation, substitution, modification, or neutrality. Secondly, to examine to what extent the geographical and sociodemographic factors affect the frequency of online shopping. Thirdly, to assess the extent to which the frequency of online shopping has increased since the pandemic period.

In the next section, the theoretical background of online shopping is briefly outlined. The third section describes the context, data sources, and the methodology. The fourth section provides the results, testing the association between the online and in-store shopping. Discussion of these empirical results with the finding of other authors follows in the fifth section. In the final section, main conclusions and policy implications are drawn.

2. Theoretical background

The following two theoretical subsections briefly discuss the key determinants and interrelationships of online and in-store shopping behaviour. Subsection 2.1 focuses on the geographic, sociodemographic, behavioural and attitudinal factors of online/in-store shopping, drawing on the innovation-diffusion and efficiency hypotheses. Subsection 2.2 explores the dynamic relationship between online and in-store shopping, distinguishing among substitution, complementarity, modification, and neutrality effects, and examining their variation across different geographical contexts.

2.1 Determinants of online shopping and in-store shopping behaviour

There is a general consensus that the intensity and frequency of online shopping is mostly affected by four basic groups of determinants: spatial, sociodemographic, behavioural and attitudinal (Farag et al., 2006a; Farag et al., 2006b; Krizek et al., 2005; Shi et al., 2021a). Starting with the former, the basic question is if the intensity of online shopping differs between the urban cores/inner cities and lower-density residential suburban and rural areas. Concerning the differences in the online shopping behaviour along the urban-rural continuum, the above-mentioned innovation-diffusion hypothesis (Anderson et al., 2003) expects the spread of online shopping behaviour from the urban cores towards remote hinterlands as a consequence of hierarchical spatial innovation diffusion. The efficiency hypothesis, on the other hand, states that higher intensity of online shopping occurs in more remote rural areas as a substitute for less accessible in-store shopping opportunities. These hypotheses are not necessarily mutually exclusive: both effects can be observed in the same urban region simultaneously (Anderson et al., 2003; Beckers et al., 2018; Farag et al., 2006a; Farag et al., 2006b).

Several arguments support the relevance of the innovation-diffusion hypothesis. New technologies emerge in urban centres (Graham & Marvin, 1996). Cities and their dense central districts allow for an access to the dense social networks based on frequent highly localised face-to-face contacts (Storper & Venables, 2004) through which the innovation can be effectively transmitted. Consumers in urban cores are expected to shop frequently online: they are generally younger, more educated, having a higher social status and income, and are networked, cosmopolitan and time constrained (Farag et al., 2006b). Frequent car users may substitute the in-store shopping for online shopping in dense urban cores with traffic congestion and limited parking possibilities.

On the other hand, in mature phases of technology adoption, the core-hinterland polarity in the intensity of online shopping is likely to gradually disappear due to improved accessibility of online shopping outside the urban regions and its adoption across different layers of society (Venkatesh et al., 2012). Similarly, Krizek et al. (2005, p. 253) argues that "…in most metropolitan areas, different areas [i.e., central business district (CBD), first- and second-ring suburbs, and exurbs] all more or less enjoy similar levels of access to technology, thereby eliminating any noticeable differences due to geography." It is also a question if the core-hinterland polarity can be detected even when controlling the sociodemographic composition of the population. Urban cores usually offer high density, diversity, and quality of shopping opportunities combined with high walkability and/or public transport accessibility. Customers willing to access shops by walking or by public transport can thus incline more to in-store shopping (Ren & Kwan, 2009). Finally, younger, educated and higher income customers are also significantly present in suburban areas, not only in urban cores.

Several authors confirmed the efficiency hypotheses (see Beckers et al., 2018 for an overview), documenting higher frequencies of online shopping in less accessible areas and accessibility as a major driver for e-commerce (Cao et al., 2013; Farag et al., 2006a; Farag et al., 2006b; Motte-Baumvol et al., 2017). Therefore, people with lower accessibility to physical stores and/or to transit facilities are constrained in their in-store shopping and should be more prone to shop online (Ren & Kwan, 2009; Y Monsuwé et al., 2004). Shi et al. (2023, p. 21) stated that "people with limited access to metro services tend to have a positive attitude toward online buying and make online purchases more frequently" (see also Loo & Wang, 2018). Correspondingly, Kim et al. (2023) showed the negative effect of local accessibility on online shopping frequency. Krizek et al. (2005) reported that the suburbanites were more likely to be engaged in online shopping compared to residents of a city and those living close to the CBD. The occurrence of traffic congestion was the only spatial factor that showed significant effect on the propensity to shop online, unlike the distance to the CBD, the distinction city/suburb or number of in-store shopping opportunities at the neighbourhood level. Therefore, sociodemographic characteristics and attitudinal factors were more important predictors than spatial variables (Krizek et al., 2005).

Other studies, however, indicate that the density of in-store shopping opportunities (Ding & Lu, 2017) or accessibility to physical stores (Etminani-Ghasrodashti & Hamidi, 2020; Lee et al., 2017) do not affect the online shopping significantly. There might be even a reverse (positive) effect between the accessibility to physical stores and online purchasing frequency (Cao et al., 2013). Consumers frequently combine shopping trips with other types of travel, such as commuting to work (Hsiao, 2009). Therefore, online shopping behaviour may respond more significantly to the departure or transit location than to the residential location (Shi et al., 2023). Consequently, recent studies have suggested that the built environment at departure locations for shopping trips, rather than residential locations, should be considered a key explanatory factor (Shi et al., 2021a). Higher population, built-up or job densities are expected to positively and directly affect the online shopping frequency.

Apart from the above-mentioned effects of the built environment, shopping behaviour is affected also by previous internet experience, sociodemographic and attitudinal variables (Shi et al., 2019; Weltevreden & van Rietbergen, 2007). Starting with the sociodemographic variables, gender, age, education, income and living costs showed significant association with the propensity to online shopping (Biswas et al., 2024; Farag et al., 2006a; Farag et al., 2006b; Shi et al., 2021a; Shi et al., 2019). Gender affected the propensity to shop online in the early stages of the technology

adoption (Maat & Konings, 2018). More recent papers, however, found either limited or no effect of the gender on online shopping behaviour (Hernández et al., 2011; Lee et al., 2015). Several studies reported decreasing gender gap in the online shopping adoption (Hernández et al., 2011), while other authors concluded that females shop online (Arranz-López et al., 2023), but also in-store (Ding & Lu, 2017) more often than males. Certain differences can be found in the preference for products online: females purchase apparel online more often, males are more likely to buy electronics online (Lian & Yen, 2014; Zhen et al., 2016). While the online shopping is frequent in the group of young graduates and higher-income males, grocery shoppers are mainly young, educated, with high incomes, and at least one child (Farag et al., 2006b).

While the evidence on the effects of age is also mixed, most authors documented negative association with the propensity to shop online (Ding & Lu, 2017; Farag et al., 2007; Irawan et al., 2015; Shi et al., 2019; Zhou & Wang, 2014). Others found a non-linear relationship: the probability of online shopping increases up to age 33 (Farag et al., 2006b; Zhen et al., 2018) or 35–39 (Clarke et al., 2015) and then declines. Individuals with a higher level of income (Zhen et al., 2016), education (Cao et al., 2012; Lee et al., 2015) and full-time employment status (Zhou & Wang, 2014) are more likely to shop online and make online purchases more frequently (see also Biswas et al., 2024). The evidence is, however, not conclusive: Ding and Lu (2017) found no significance, and Irawan et al. (2015) an even more negative effect of education and income. However, this does not mean that the gender, age, and income differences do not exist, because they affect the capacity of individuals to overcome the initial barriers and adopt e-commerce (Hernández et al., 2011). On the other hand, when shopping in physical stores, factors such as the type of store (Spilková, 2018) and opening hours (Mulíček & Osman, 2018) may play a key role in determining where certain groups of people choose to shop. Spilková (2018) demonstrated that each type of store attracts a specific customer profile. For instance, smaller local stores are typically frequented by women over 65 years old, while convenience stores are predominantly visited by men aged 18 to 35. Similarly, shopping centres tend to attract teenagers more frequently than seniors (Križan et al., 2018; see Trembošová et al., 2022 for contrasting results). Generally, age plays a role in terms of who tends to shop in brick-and-mortar stores more often. Kleisiari et al. (2021) found, that elderly people tend to visit shops more often, and gender impacts only a certain type of goods (Manko & Jose, 2022). As already suggested, behavioural and attitudinal variables also affect the online shopping (Farag et al., 2006a; Hernández et al., 2010). Acceptance of the Internet (Davis et al., 1989), Internet experience (Ren & Kwan, 2009), frequency of Internet use (Cao et al., 2013; Ding & Lu, 2017; Maat & Konings, 2018; Shi et al., 2019), perceived self-efficacy in online shopping, risk perception and perceived quality of vendors stimulates the use of the Internet (Farag et al., 2006b). Importantly, Hernández et al. (2011) found that sociodemographic variables (gender, age, income) moderate the relationships between the attitudinal variables and online shopping, but these effects cease to be significant in the group of respondents who have acquired an experience with online shopping.

2.2 Online shopping and in-store shopping: mutual relationships

Empirical evidence on the relationship between the online shopping and in-store shopping is rather conflicting (see Le et al., 2022 or Shi et al., 2019 for a comprehensive review). Mixed or bidirectional effects (Farag et al., 2007; Zhou & Wang, 2014) were commonly observed. Several authors found the substitution effect (e.g., Irawan et al., 2015; Shi et al., 2019; Suel & Polak, 2017; Weltevreden & van Rietbergen, 2009; Weltevreden & van Rietbergen, 2007). While in the early phases of the e-commerce adoption substitution was considered to be marginal (Gould & Golob, 1998), recent papers documented more substantial reduction of travelling for shopping. For example, Weltevreden and van Rietbergen (2007 and 2009) indicated that 20% of respondents answered that they actually reduced their shopping trips due to online shopping.

Importantly, the existence of the substitution or complementarity effect may be affected by transport mode. Substitution effect is more likely for the people with no car (Shi et al., 2019). Online shopping can reduce the frequency of car shopping trips more than the frequency of public transport trips and walking (Bjerkan et al., 2020; Suel & Polak, 2017), while also contradictory evidence exists. Etminani-Ghasrodashti and Hamidi (2020) found a negative association between the online shopping and car/public transport use for shopping travel, supporting the efficiency hypothesis. Correspondingly, Weltevreden and van Rietbergen (2009) concluded that the shop accessibility and travel time to shopping centres affect the decision if online shopping is substituted for in-store shopping: substitution is more likely for consumers who have few shopping opportunities or need to travel large distance to the shopping centre.

Findings supporting the existence of the complementarity effect are also numerous (e.g., Cao et al., 2010; Ding & Lu, 2017; Farag et al., 2006a; Farag et al., 2006b; Lee et al., 2017; Zhen et al., 2016; Zhou & Wang, 2014). Farag et al. (2006a) documented that people who shop online tend to buy in-store more frequently. Cao et al. (2010) reported that nearly half of their respondents were motivated to make a new shopping trip to the physical store after seeing goods online. Correspondingly, Cao et al. (2012) documented the positive effect of online shopping on the frequency of physical shopping trips, imposing an extra burden on existing urban transportation systems. Only a few studies documented the neutrality effect (Calderwood & Freathy, 2014; Hiselius et al., 2015; Mokhtarian, 2002).

While the modification effects on the frequency of shopping trips were also rarely found (Ding & Lu, 2017), the modification effects on the transport mode choice and time-use were more common. Specifically, decreased car trips and reductions of the travel/shopping duration were observed (Bjerkan et al., 2020; Shi et al., 2021b). Surprisingly few studies have focused on the determinants of whether people reduce or increase their shopping trips due to their online shopping. Weltevreden and van Rietbergen (2009) found that for non-daily goods, substitution effect is more likely for the frequent online purchasers, younger respondents, and people with low accessibility to shops. Although gender and education did not play a significant role, age has a nonlinear effect on the probability of reducing shopping trips (Shi et al., 2019).

The effects of online shopping on in-store shopping may vary substantially across different geographical contexts, urban-rural continuum (Anderson et al., 2003; Farag et al., 2006b; Cao, 2009) and between different types of neighbourhoods inside metropolitan regions (Arranz-López et al., 2024; see also Gao et al., 2025). Several authors argued that the substitution is more likely to occur in small towns and rural centres or shopping centres at the edge of cities, while larger city centres can more easily switch from retail to service and leisure functions (Dixon & Marston, 2002). Frequent e-shoppers in German urban counties and rural areas were found to drive more frequently to in-store destinations (Arranz-López et al., 2024, p. 7) than respondents living in large cities. Weltevreden and van Rietbergen (2009, p. 296) found the opposite: city centres are most likely to face substitution of online shopping for in-store shopping, while Shi et al. (2019) found non-significant effects of urban, suburban, and exurban neighbourhoods. On the other hand, consumers who need to travel larger distances to the shopping centre and customers with few shopping opportunities are more likely to substitute for online shopping (Weltevreden & van Rietbergen, 2009, p. 297). Interestingly enough, consumers living in neighbourhoods with

low street density tend to substitute online shopping for car trips: longer travel distance to brick-and-mortar shops increases the potential for substitution (Li et al., 2025, p. 265).

3. Data and methods

At the beginning, a brief geographic characteristic of The Ostrava Metropolitan Region (OMR) will be presented. OMR spans most of the Moravian-Silesian Region, representing the second-largest metropolitan area in the Czech Republic in terms of population and land area, with nearly 1 mil. residents and an area of 2,710 km^2 (ITI, 2020). The metropolitan region includes an urban core centred around the city of Ostrava (approximately 295,000 inhabitants), which serves as a crucial economic and administrative hub. More than 50,000 residents of the metropolitan area commute to Ostrava daily (ČSÚ, 2021), underscoring its central role in regional connectivity and employment. In terms of purchasing power, the region stands at 71% of the EU27 average (Purchasing Power Standard, PPS, EU27 = 100, 2020) per inhabitant (Eurostat, 2024).

During the 19th and 20th centuries, the metropolitan region experienced rapid population growth driven by heavy industry and mining. However, following the collapse of the communist regime in 1989 and subsequent deindustrialisation, nearly all major cities in the region have faced population decline. This trend is attributed to the incomplete transformation of the regional economy, coupled with outmigration and demographic transition. While selected smaller municipalities within the metropolitan area have experienced population growth, primarily due to suburbanisation (Slach et al., 2019), the overall population of the region continues to decline.

As a result of this historical development, the urban structure of Ostrava has taken on a fragmented, polycentric and erratic urban form (Slach et al., 2019). Zarecor (2018) refers to Ostrava as a 'triple city', highlighting the fact that the historical city centre remains relatively small and spatially disconnected from the main population hubs of the city, such as the districts of Poruba and Ostrava-Jih. This phenomenon is not unique to Ostrava but is common across other cities in the region that experienced both rapid, uncoordinated expansion and later socialist-era planning. Instead of building upon the existing historical urban fabric, socialist planning often sought to implement entirely new ideas about the 'ideal socialist city', further contributing to the disjointed spatial organisation seen today (e.g., cities of Havířov, Frýdek-Místek, and Orlová). The overall weakness of spatial planning since 1989 has further contributed to the polycentric settlement structure of the metropolitan region, reinforcing its fragmented character.

From the perspective of retail network development, the metropolitan region has been shaped by the dynamic expansion of shopping centres and other large-format retail stores since 2000. This development has led to a highly saturated retail network (Križan et al., 2021) even in rural areas (Sadílek et al., 2023), addressing the underdeveloped infrastructure inherited from the socialist era. While the greenfield 'out-of-centre' shopping centres between 5,000 and 20,000 sqm prevail, the share of brownfield shopping centres in urban cores has been increasing (Križan et al., 2021). While the large centrally located shopping centres increase the range of shopping possibilities, they may also negatively affect the density, quality, and vitality of retail in the urban cores, as documented on the case of Nová Karolína close to the historical centre of Ostrava (Slach et al., 2019).

In the next step, the consumer behavioural patterns in the OMR were analysed and tested the effects of selected sociodemographic, geographic, and attitudinal/behavioural variables (Tab. 1) on the frequency of online shopping in three subsequent steps. Firstly, basic descriptive statistics and GIS analysis was conducted to display the differences among various sociodemographic groups and map the geography of current online shopping in the Ostrava metropolitan region. These data can be explored in more detail through a supplementary interactive dashboard, which enables filtering by sociodemographic and spatial characteristics. In the second step, bivariate relationships between variables capturing various aspects of online shopping behaviour and preferences in relation to in-store shopping on one hand and explanatory variables on the other were tested. The aim was to determine the association between the shopping behaviour and individual sociodemographic and geographic factors. Thirdly, there was an aim to explain differences among respondents in the frequency of online shopping by a general linear model testing the effects of the frequency of online shopping, ways of spending time, commuting, and sociodemographic and geographical indicators. Our methodology was based on a general linear model integrated with an interactive dashboard to visualise data through graphs and charts rather than full-scale spatial mapping. This approach,

Variable	Description
Potacc	Potential accessibility of the ZIP-code areas (centroids) in the Ostrava metropolitan region, weighted by their population (2021 Census)
Shopacc	Geographic accessibility (mean distance) of the shops from the ZIP-code area centroid
Neighbourhood	Where is your current permanent residence (typology of the neighbourhood)? 1 = towns with more than 20,000 inhabitants; 2 = Ostrava (high-density neighbourhoods; 3 = Ostrava (low-density neighbourhoods); 4 = towns and municipalities with less than 20,000 inhabitants.
Dist-serv	How far from your place of residence do you usually purchase services (trips, massages, internet TV, repair services)?
Shop-distant	To what extent (1–5 Likert scale) do you agree with the statement: "Most frequently I shop at stores in more distant locations from my residence (over 30 minutes walking or over 5 kilometres)"?
Time-online	How much time do you spend on the internet in your free time? 1 = only a couple of hours weekly; 2 = less than 3 hours weekly; 3 = 3–5 hours weekly; 4 = more than 5 hours daily.
Time-work	How many hours per week do you spend at work/school (including commuting)? 1 = 2 hours; 2 = 4 hours; 3 = 6 hours; 4 = 8 hours; 0 = I do not work.
Time-car (pubtrans/walk)	How much time do you usually spend driving (commuting by the public transportation/walking) to the store for shopping per week?
Freq-store	How often do you shop in a brick-and-mortar store? 1 = daily; 2 = 1–3× a week; 3 = at least 4× a week; 4 = at least once monthly; 0 = never.
Freq-online	How often do you shop online? 1 = daily; 2 = 1–3× a week; 3 = at least 4× a week; 4 = at least once monthly; 0 = never.
Freqon-c19	How often did you shop online before the pandemic (February 2020)? 1 = daily; 2 = 1–3× a week; 3 = at least 4× a week; 4 = at least once monthly; 0 = I did not shop online at all.
Limit-car	Did you limit car usage for shopping due to online purchasing during last three years? 1 = yes (up to 20% reduction); 2 = yes (20–49.9% reduction); 3 = yes (50–69.9% reduction); 4 = yes (more than 70% reduction); − 1 = Currently I use the car for shopping more than before; 0 = I have never used car for shopping.
Gender	0 = male; 1 = female; 9 = prefer not to say/other
Age	years (cardinal variable)
Education	1 = elementary; 2 = secondary (vocational); 3 = high school (graduated); 4 = higher professional; 5 = university level
Social status	1 = student; 2 = employee; 3 = entrepreneur; 4 = retiree; 5 = person on maternity/parental leave
Income	1 = < 10,000; 2 = 10,000–19,999; 3 = 20,000–29,999; 4 = 30,000–39,999; 5 = 40,000–59,999; 6 = 60,000–79,999; 7 = 80,000–99.999; 8 = > 100,000

Tab. 1: Variables used in the statistical analysis
Source: Authors' conceptualisation

which emphasises statistical analysis of spatially referenced data, has proven effective in revealing consumer behaviour patterns in e-commerce (Ding & Lu, 2017; Kim et al., 2023). Additionally, De Miguel González et al. (2025) demonstrated the effectiveness of integrated GIS dashboards in supporting interactive data visualisation and decision support across various domains, further validating our methodological approach.

3.1 Data collection

In this research, a data collection method was employed using a questionnaire survey, which is commonly used in studies examining shopping behaviour (see Farag et al., 2006b; Hsiao, 2009; Francke & Visser, 2015; Shi et al., 2019). Structured online questionnaires were used that covered close-ended multiple-choice and scale questions focusing on respondent's (online) shopping behaviour, habits, and preferences. Convenience sampling strategy was employed. Respondents were selected according to three criteria:

i. they participated on research projects of the authors of this paper in the past as respondents (including students of the University of Ostrava);
ii. they live, work, or study in the OMR; and
iii. they are interested and engaged in the urban development of the OMR.

As respondents in the current research are reached online (Andreou et al., 2025; Pucelj et al., 2024), the questionnaire was disseminated by social media (Facebook and Instagram groups of local cities and districts) and emails to the target groups of respondents. The response rate was increased by sending direct emails to the respondents. The survey was conducted during September and October 2023 and yielded 468 valid questionnaires. Homogeneity of the dependent ordinal variables was tested by the Kruskall-Wallis test, homogeneity of cardinal variables by the ANOVA. The results show no significant effects of the sampling strategy on the values of observed variables. However, the sample cannot be considered representative for the population in Ostrava metropolitan region. Females (72.7%), students (50.6%) and respondents with completed university education (33.1%) are heavily over-represented. Nevertheless, our intention was not to infer empirical conclusions to regional population. Instead, our inferential statistical analysis was focused on uncovering the patterns of individual shopping behaviour.

3.2 Data analysis and model building

For the description of consumer behavioural patterns, mostly frequencies and median values that are appropriate for the categorical variables were used. Bivariate relationships between the frequency of online (and in-store) shopping and explanatory sociodemographic, behavioural/attitudinal and geographical variables were tested according to the scale of variables (Tab. 2): chi^2 square test for Gender; Kendall tau-b/tau-c for Education, Income, Social status, Time-online, Time-work, Time-car, Time-pubtrans, Shop-distant, Neighbourhood and finally; ANOVA for the Age, Potential accessibility and Shop accessibility. The key emphasis was on the geographical variables, represented by the Potential accessibility (Potacc), Shop accessibility (Shopacc) and the variable Neighbourhood. The variable Potacc was used to test the effects of the transport accessibility that indirectly represents the shop accessibility at the metropolitan scale and might be associated with lower frequency of online shopping (Shi et al., 2023; while Lee et al., 2017 or Etminani-Ghasrodashti & Hamidi, 2020 found insignificant results). Accessibility of shops in the neighbourhood might also display a negative relationship with the frequency of online shopping (Ren & Kwan, 2009; Shi et al., 2023; Wei et al., 2024). Finally, the variable Neighbourhood captures the position of the settlement in the urban-rural continuum to test the innovation-diffusion and efficiency hypothesis (Anderson et al., 2003) and associated effects of residential density (following Shi et al., 2023; Arranz-López et al., 2024; Xu & Saphores, 2024 or Li et al., 2025) and centrality in the metropolitan region (Wei et al., 2024). In the next step, the general linear model was conducted with the frequency of online shopping as a dependent variable, age, potential accessibility of ZIP-code areas, and geographical accessibility of the shopping centres as covariates and gender, education, income, social status, frequency of in-store shopping, neighbourhood typology (definition in Tab. 1), time spent by the online shopping, time at work, time spent commuting for services and time spent by the labour commuting (following and developing approach of Shi

Variables	Results	Interpretation
Relationships with the Frequency-online		
Time-work	tau-c = − 0.022; p = 0.538	Not significant
Time-car	tau-c = − 0.090; p = 0.006	People who commute longer distances by car to the shops tend to shop online more frequently
Time-public transport	tau-c = 0.043; p = 0.214	People who commute longer distances by public transport to the shops tend to shop online less frequently
Time-walking	tau-c = 0.043; p = 0.236	Not significant
Time-online	tau-c = 0.073; p = 0.040	People who spend more of their free time on the internet shop online more frequently
Shop-distant	tau-b = − 0.045; p = 0.244	Not significant
Dist-serv	tau-c = 0.106; p = 0.001	People who commute longer distances to purchase services tend to shop online less frequently
Gender	chi^2 = 11.896; p = 0.292	Not significant
Age	F = 1.607; p = 0.157	Not significant
Education	tau-c = -0.131; p<0.001	Educated people shop online more often
Income	tau-c = -0.116; p<0.001	Ambiguous relationship, people with higher income shop online more
Potacc	F = 2.136; p = 0.060	People living in more accessible areas shop online less frequently
Shopacc	F = 2.310; p = 0.043	People living close to shopping centres shop online less frequently
Freq-store	tau-c = 0.019; p = 0.523	Not significant
Relationships with the Limit-car		
Freqon-C19	tau-c = 0.090; p = 0.018	People who shopped online more frequently before the pandemic reduced the car usage more
Time-online	tau-c = 0.117; p<0.001	People who spend more time online reduced the car usage more than people who spend less time online
Gender	chi^2 = 23.789; p = 0.022	Males reduced the car usage less than females
Age	F = 3.283; p = 0.004	Significant, yet ambiguous effect of age
Education	tau-c = 0.038; p = 0.235	Not significant
Income	tau-c = 0.014; p = 0.688	Not significant
Social status	chi^2 = 69.160; p = 0.024	Employees reduced the car usage more than students
Potacc	F = 0.919; p = 0.481	Not significant
Shopacc	F = 0.850; p = 0.532	Not significant

Tab. 2: Patterns of the respondent's shopping behaviour: bivariate relationships
Source: Authors' calculation

et al., 2023). Potential spatial autocorrelation of the variables employed in the model by the Moran's I test was tested, and no strong spatial autocorrelation was detected (I = 0.065; p = 0.095).

4. Results

For better understanding, a brief summary based on the results of descriptive statistical analysis, focusing on the changes during the COVID-19 pandemic is presented first. In the metropolitan region of Ostrava, the number of consumers shopping online at least once a month has increased by almost 17%. Females have increased the frequency of online shopping more than males during the pandemic. However, this might be explainable by the fact that males had already been more frequent online shoppers compared to women before the pandemic. On the other hand, only 11% of respondents reduced car usage by 50% or more, and another 13% reduced the car usage by at least 20%. Importantly, when student respondents are excluded, the car remains the dominant mode of transportation for in-person shopping, with 84% of people using it. In contrast, only 34% of non-students rely on public transport for shopping. Despite a minor increase of the intensity and frequency of online shopping during the pandemic period, in-store shopping is still the dominant mode of purchasing products (see also Kunc et al., 2024). Nearly 90% of respondents still buy some products in brick-and-mortar shops at least once a week, while only 9% of respondents shop online with same frequency.

According to the results of the survey, most people still prefer in-store shopping for some sorts of goods: mainly food (up to 5 km from their home by 69% of respondents) and clothes. Services, on the other hand, are often purchased online (reported by 35% of respondents). When shopping online, clothes (70% of respondents) and leisure equipment (65% of respondents) are dominant products. Surprisingly only 54% of respondents who buy products online also buy services in online environment. An interesting fact is that, apart from goods delivered directly online (such as digital products), a majority of people today (74%) prefer having their orders delivered to pick-up points, such as post offices, parcel lockers, or specialised collection services. In contrast, only 13% of people choose home delivery.

In the next step, sociodemographic characteristics of respondents were associated with their shopping behaviour and preferences, starting with the frequency of online shopping. While people living outside urban areas with limited accessibility should benefit substantially from online shopping, their frequency of online shopping was similar to the respondents living in urban cores, despite their higher commuting distance (Fig. 1). On the other hand, the urban-rural dichotomy is visible in case of services that are purchased online more frequently by the people living outside urban areas. No significant differences between the income groups were found. 70% of males purchased online at least once a month, while only 56% of women shopped online with the same frequency (see Kunc et al., 2024 for similar finding). 62% of people using internet on daily basis purchased goods and services online at least once a month, while 53% of people not using the internet on a daily basis buy goods and services online with the same frequency.

In the second step bivariate statistical tests were conducted of the association between the frequency of online shopping and selected sociodemographic, geographical and behavioural/attitudinal variables (Tab. 2). No relationship between the time spent at work (busy lifestyle) and frequency of online shopping was found. Indicators of commuting to shops were only partially relevant. Longer commuting by car to the shops was positively associated with the frequency of online shopping, suggesting possible substitution effect. Surprisingly, the opposite effect was found in case of people who commute long distances by the public transport. Attitudinal variables matter in that people who spend more time on the internet tend to shop online more frequently. More importantly, higher frequency of online shopping is associated with longer commuting for purchasing of services. While gender and age showed no significant effect, the tests proved that more educated and higher-income respondents exhibit higher frequency of online shopping.

Considering the sociodemographic indicators, gender, age, and social status, showed a significant association with the dependent variable Limit-car. Reduction of car commuting to shops was stronger for females than males and for students rather than for employees. There were no systematic spatial patterns in the reduction of car commuting to the shops. Most importantly, higher frequency of online shopping before the COVID-19 pandemic was associated with higher reduction of car trips to the shops.

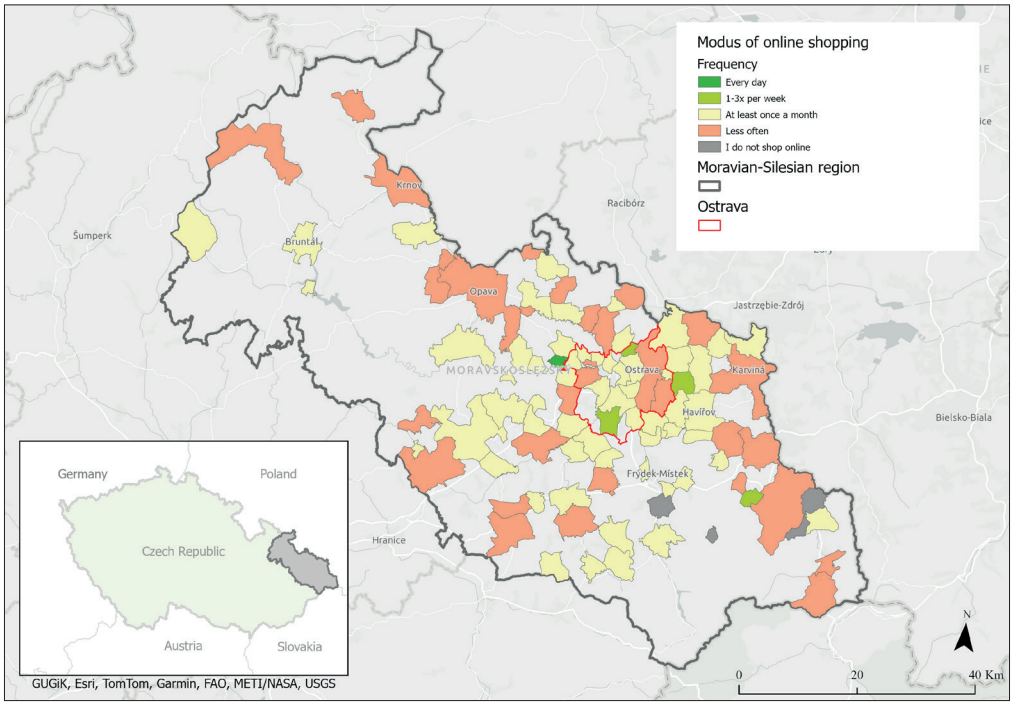

Fig. 1: Frequency of online shopping behaviour: regional differences
Source: Authors' elaboration

To explain individual variations in the frequency of online shopping, the general linear model (Tab. 3) was employed. Out of all indicators capturing the distance between the residence and place of shopping, only the distance to the place where services are purchased proved to be relevant and was retained in the final model. Similarly, the transport modes used for shopping were also removed from the model, except for commuting by car. Apart from the sociodemographic variables (gender, age, education, social status, income) two types of geographical variables were a matter of focus. The first type was represented by the individual distance-based indicators of commuting (Time-car, Dist-serv, Shopacc) and the neighbourhood-level characteristics: population size and density captured by the indicator Neighbourhood and population-weighted potential accessibility (Potacc). Finally, attitudinal variables were captured by the indicators reflecting the way of spending time (Time-work, Time-online).

The model explained 58.8% of total variability of the frequency of online shopping. The most surprising finding is non-significant effect of any neighbourhood-level characteristic. Association between the online shopping frequency and potential accessibility of the zip-code areas and even the accessibility of shopping centres is negligible. The only geographical variable that mattered is the time spent by driving to the shops weekly (Time-car): respondents who spend less time by the commuting to the shops by car shop online less frequently. Frequency of online shopping was not significantly affected by gender, age and social status. Education and income showed weak association with the dependent variable. Respondents with university education and higher income reported that they were shopping online more often. The single most important predictor of the frequency of online shopping was the attitudinal variable Time-online. A strong positive effect of the weekly amount of time spent on the internet on the frequency of online shopping was documented. Importantly, another attitudinal variable: frequency of in-store shopping, was not associated with the frequency of online shopping.

Finally, there was an aim to determine if the changes in the frequency of online shopping before and after the COVID-19 pandemic contributed to the reduction of the car usage for in-store shopping. Model 2 shows rather weak and insignificant effects of the sociodemographic and geographical predictors (Tab. 4). Reduction of the car usage was positively affected by the time spent by commuting to the shops by car and by the car usage before the COVID-19: respondents who commute longer distances and who used the car for commuting to the shops reduced the car usage more.

	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	387.603[a]	50	7.752	11.919	.000
Intercept	9.383	1	9.383	14.427	.000
Time-work	2.662	4	0.666	1.023	0.395
Time-car	5.353	3	1.784	2.743	0.043
Time-online	309.575	5	61.915	95.193	0.000
Gender	0.032	2	0.016	0.025	0.975
Age	0.259	1	0.259	0.398	0.529
Education	4.934	4	1.233	1.896	0.110
Social status	3.153	8	0.394	0.606	0.773
Income	8.248	7	1.178	1.812	0.083
Freq-store	1.683	5	0.337	0.517	0.763
Dist-services	5.685	6	0.947	1.457	0.192
Neighbourhood	0.637	3	0.212	0.327	0.806
Potacc	0.001	1	0.001	0.001	0.974
Shopacc	0.075	1	0.075	0.116	0.734
Error	271.224	417	0.650		
Total	8,219.000	468			
Corrected Total	658.827	467			
R Squared = 0.588 (Adjusted R Squared = 0.539)					

Tab. 3: Model 1 (general linear model, dependent variable: frequency of online shopping). Source: Authors' calculations

	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	122.862[a]	48	2.560	1.730	0.003
Intercept	0.036	1	0.036	0.024	0.876
Time-work	6.932	4	1.733	1.171	0.323
F63_distan	3.797	6	0.633	0.428	0.860
Time-car	18.217	3	6.072	4.104	0.007
Time-online	5.893	4	1.473	0.996	0.410
Gender	4.888	2	2.444	1.652	0.193
Age	0.259	1	0.259	0.398	0.529
Education	0.755	4	0.189	0.127	0.972
Social status	13.297	8	1.662	1.123	0.346
Income	7.610	7	1.087	0.735	0.643
Freq-store	3.488	3	1.163	0.786	0.502
Dist-services	22.513	4	5.628	3.804	0.005
Neighbourhood	0.070	1	0.070	0.048	0.827
Potacc	0.007	1	0.007	0.005	0.946
Shopacc	0.078	1	0.078	0.052	0.819
Error	588.860	398	1.480		
Total	1,028.000	447			
Corrected Total	711.723	446			
R Squared = .173 (Adjusted R Squared = .073)					

Tab. 4: Model 2 (general linear model, dependent variable: Limit-car) Source: Authors' calculations

5. Discussion

There is no significant association between the frequency of online shopping and in-store shopping, suggesting the existence of neutral effect of the former on the latter (in line with findings of Mokhtarian, 2002, Calderwood and Freathy, 2014, or Hiselius et al., 2015). Neither the substitution nor the complementary effect was thus observed during the COVID-19 pandemic. Correspondingly, assumptions were also not confirmed that lower shop accessibility and poor shopping opportunities increase the likelihood of the substitution effect, as suggested by Weltevreden and van Rietbergen (2009). The neutrality indicates that the impact of e-commerce on diminishing the vitality of urban centres is likely to be limited (Slach et al., 2020). Respondents who reported more frequent online shopping did not exhibit lower propensity for in-store shopping, regardless of the transportation mode.

Neither the findings that the substitution effect is more likely for people with no car (Shi et al., 2019) nor the suggestions that online shopping reduces car commuting to the shops more that the frequency of public transport shopping trips or walking (Bjerkan et al., 2020; Suel & Polak, 2017) were confirmed. The above-mentioned observed neutral effect may be partly attributed to the continued importance of in-store shopping, which remains a significant leisure activity. Often referred to as 'fun shopping', it is frequently combined with other activities, such as dining or socialising, making it a valued and multifaceted part of urban life that online shopping cannot fully replicate (Spilková, 2012). To summarise, our expectation that the growing intensity of online shopping during the pandemic would reduce traffic flows associated with the in-store shopping was not supported by the empirical evidence. This result was affected by rather minor changes of shopping behaviour during the pandemic era: see also Fuentes et al. (2022), Demyen (2024) or Pucelj et al. (2024) for similar results. In our case, 10.6% respondents reported increasing frequency of their online shopping, while 64% of them reported no change. The assumption that the substitution effect is more likely in small towns/rural centres or shopping centres or at the edge of cities was not demonstrated. In contrast with the age effects observed by Shi et al. (2019) or Weltevreden and van Rietbergen (2009), non-significant effects of the sociodemographic variables were detected.

Returning to the initial debate about the innovation-diffusion and efficiency hypothesis Anderson et al. (2003), empirical support for neither was found. Spatial patterns of online shopping behaviour are not substantially correlated with geographical variables. The frequency of online shopping is only slightly higher in small towns in the wide metropolitan hinterland of Ostrava, but the difference is not statistically significant. Our results confirm the conclusions of Krizek et al. (2005) that different areas in metropolitan regions enjoy roughly similar access to online shopping, reducing thus the differences caused by geography. In addition, recent paper by Kunc et al. (2024) focusing on generation Z in the Czech Republic also did not prove significant differences in shopping behaviour between large cities, smaller towns, and rural municipalities. Due to intensive suburbanisation, higher income, educated, networked, and cosmopolitan urbanites reside not only in urban cores (see Farag et al., 2006b), but are significantly represented also in some small towns and rural municipalities in the metropolitan hinterland.

Despite higher density, diversity, and quality of shopping opportunities combined with walkability and public transport accessibility, the urban core of Ostrava did not exhibit higher frequency of in-store shopping (in contrast with conclusions of Ren and Kwan, 2009). Although slightly higher empirical support for the efficiency hypothesis was found, no significant effects of the distance to the CBD, potential accessibility or shop accessibility were found. This can be partly explained by generally high accessibility of brick-and-mortar shops in rural municipalities (Sadílek et al., 2023). Our results correspond with findings of Ding and Lu (2017); Etminani-Ghasrodashti and Hamidi (2020); Lee et al. (2017), while contrast with Beckers et al. (2018); Cao et al. (2013); Farag et al. (2006a); Farag et al. (2006b); Kim et al. (2023); Motte-Baumvol et al. (2017); Ren and Kwan (2009); Shi et al. (2023).

Empirical results confirmed the conclusions of Krizek et al. (2005) that sociodemographic characteristics and attitudinal factors (such as using smartphones for payment: see Kunc et al., 2024) were stronger predictors than spatial variables. The assumption of closing gender gap in mature phases of the technology adoption (Hernández et al., 2011) was confirmed, while males reported somewhat (not significantly) higher frequency of online shopping (Kunc et al., 2024). In sharp contrast with the most common findings (Ding & Lu, 2017; Farag et al., 2007; Irawan et al., 2015; Shi et al., 2019; Zhou & Wang, 2014; Vinerean et al., 2024), increasing (while not significant) frequency of online shopping with growing age was found. This can be attributable to lower income of students in the sample: when controlling for income and social status, the effect of age ceases to be significant.

Education, income, and social status showed positive effects on the frequency of online shopping, confirming previous evidence of Zhen et al., (2016), Lee et al. (2015), Zhou and Wang (2014) or Berke et al., (2025). Therefore, educated, higher-income individuals and employees are more likely than other sociodemographic groups to shop online. More importantly, behaviour and attitude showed by far the strongest positive effects on the frequency of online shopping. While Ding and Lu (2017), Cao et al. (2013), Maat and Konings, (2018) or Shi et al. (2019) documented the effects of the frequency of using the internet, a very strong positive effect of the time spent weekly online was found. This finding suggests that the online shopping behaviour is driven more by a hedonic lifestyle than by reasons of necessity or cost saving. On the other hand, a 'busy lifestyle' measured by the time spent at work was not associated with shopping behaviour.

6. Conclusions

This paper aimed to explain current intra-metropolitan differences in the frequency of online shopping and their potential relationships with in-store shopping. Two canonical hypotheses were tested: the innovation-diffusion hypothesis suggesting higher e-commerce adoption in the urban core and the efficiency-hypothesis, expecting higher intensity of online shopping in remote areas to substitute for less accessible in-store shopping opportunities. The authors were drawing upon a case study of Ostrava, a medium-sized polycentric industrial agglomeration with relatively weak urban core and high accessibility of shopping centres and pick-up points in the metropolitan hinterland. In a mature phase of the e-commerce adoption, no significant spatial differences in the frequency of online shopping are likely to manifest in this type of metropolitan region. Apart from the spatial factors, the effects of sociodemographic, behavioural and attitudinal variables were also tested, focusing also on the changes during the COVID-19 pandemic.

Empirical support, neither for the substitution nor for the complementarity effect was found: growing intensity of online shopping does not reduce the frequency of in-store shopping. While the consumers who commute long distances to the shops by car shop online more frequently, online shopping does not contribute to an actual reduction of the intensity of car transportation (but also other transport modes) in the metropolitan area. Surprisingly, the substitution effect did not even occur in the COVID-19 pandemic period despite a small general increase in the frequency of online shopping. More generally, the pandemic period did not alter the pattern of shopping behaviour substantially and did not lead to any systematic reduction of in-store shopping. Considering the environmental aspects of shopping in the metropolitan region of Ostrava, the lack of an actual reduction of the intensity of transport flows is considered negative in regard to the quality of life in this heavily polluted area. Future research is needed to determine if this finding is valid also for other Central European regions that rely heavily on individual car transportation despite an extensive public transport network.

Three empirical findings that correspond with previous evidence from different geographical contexts (see Discussion) seem to have general validity. Firstly, the effects of spatial factors on intra-metropolitan patterns of online shopping are obscured by the sociodemographic indicators, especially education and income. Therefore, frequency of online shopping responds to the spatialities of educated and higher-income consumers more than to the urban form, centrality or (shop) accessibility. Secondly, no significant current intra-metropolitan spatial patterns of online shopping behaviour were detected. The COVID-19 pandemic did not alter substantially the geography of shopping behaviour in the metropolitan region. Despite slightly higher frequency of online shopping in several small-to-medium-sized towns in the metropolitan hinterland, our empirical evidence supported neither the innovation-diffusion nor the efficiency hypothesis. Geographical factors including the urban form (type of neighbourhoods) population density, centrality or accessibility of shopping centres did not affect the frequency of online shopping substantially, although the (shop) accessibility showed a statistically significant bivariate association with the frequency of online shopping. Non-existence of the core-periphery (urban-rural) pattern can be explained by the mature phase of the e-commerce adoption (Venkatesh et al., 2012), high internet coverage and dense network of pick-up points allowing for the online shopping in rural areas. Thirdly, behavioural/attitudinal variables are by far the most important predictors of the online shopping behaviour, as demonstrated by the strong positive effect of the time spent online on the frequency of online shopping. Decisions to purchase the goods and services online are probably mostly driven by price and convenience (Kunc et al., 2024) and perhaps also by the lifestyle/hedonic factors rather than by any systematic effects of sociodemographic or spatial variables.

Besides the theoretical implications, several managerial contributions based on the empirical results may be suggested. Given the neutral relationship between the frequency of in-store and online shopping, retail managers should not view e-shops as a threat to their existence. Instead, they should integrate both channels to expand the range of shopping opportunities and the quality of services. Innovative solutions combining online shopping with an in-store experience, such as the augmented reality mirrors, virtual try-ons, social livestream shopping, can be effective. In addition, in-store shopping is still dominant, particularly for clothing and groceries. Therefore, retailers should continue investing in brick-and-mortar stores and combine them with online shopping opportunities, especially in central and well accessible urban locations. The study indicates that online shopping behaviour is strongly influenced by individual lifestyle and time spent online rather than geographical factors. Managers should prioritise digital marketing strategies targeting internet-heavy users and emphasise convenience and personalisation. Finally, since online shopping has not significantly reduced the frequency of in-store shopping trips, urban planners should not assume the reduction of traffic congestion resulting from the expansion of e-commerce. Therefore, cargo bikes, local delivery hubs, and other sustainable delivery models should be prioritised.

Considering the study's limitations, unavailability of statistical data in a time series did not allow tracing reliably causal effect of the frequency of online shopping on the in-store shopping frequency. Empirical evidence of the substitution effect based on the results of cross-sectional testing should be understood as indicative only. Secondly, non-random sampling bias associated with the convenience sampling strategy leads to the overrepresentation of younger, more educated and digitally active individuals. Non-representativity of the sample does not allow for generalisation to the regional population and to other metropolitan regions. While the empirical results provide deeper insight into the sociodemographic and geographical factors of online shopping, it is not possible to use them for direct inter-regional comparisons. Thirdly, regarding shop quality, personal preferences and emotional factors such as the brand loyalty were not considered. Respondents do not necessarily have to consider the nearest shopping centres only.

Future studies can focus more on the lifestyle and attitudinal predictors of the shopping behaviour. Individual preferences, brand loyalty, and general shopping habits combined with the need of daily social networking, such as preference of small shops close to the place of residence or malls, should be considered and tested. Even more importantly, customers' experience, habits, and ways of using information technologies requires more attention, as it appears to be a key explaining factor of online shopping behaviour. Finally, a comparative case study of two medium-sized cities with different morphologies and spatial networks of shopping centres can shed more light on the effect of the urban form and related geographical variables.

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Data accessibility

All research data, related to this text, are available at the following link: https://doi.org/10.5281/zenodo.17098148

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