TRiSS Working Paper Series

No. TRiSS-WPS-02-2019

Version 1

What Drives the Gender-Cycling-Gap? Census Analysis from Ireland[1]

William Brazil, James Carroll, and Eleanor Denny

School of Economics

14th January 2019

Abstract

Switching from car to bicycle would reduce the environmental impact of personal travel and improve the physical health of commuters. Cycling rates have been increasing in Ireland over the last ten years, but there is now a large difference in male and female participation – only about a quarter of cyclists on Irish roads are female. This paper explores what factors drive this "gender-cycling-gap", with the goal of identifying policies which will make cycling more accessible to females as a means of commuting. We combine the latest census data with a geospatial survey on cycle lane density for Dublin, and apply standard regression techniques. Specific attention is given to the role of cycling infrastructure in increasing participation rates. For both males and females, increased distance to city, living in an apartment and having young children reduce participation rates, while education has a strong positive effect. However, the effects of education, distance and apartment living are considerably stronger for women. Furthermore, areas with higher shares of female professionals, controlling for other factors, are found to have lower participation rates. We find no relationship between the provision of cycling infrastructure and participation which suggests that the provision of cycle lanes in their current form are possibly not meeting the needs of potential new cyclists and providing access to the key employment areas within the city.

Keywords: Cycling, gender, transport infrastructure

Primary discipline: Economics

[1] This is a working paper and is subject to change. Please contact the authors should you wish to cite this paper.

1 Introduction and Background

Increased cycling participation is a means to address a number of the social and environmental issues associated with a transportation system built upon the convenience of the internal combustion engine. Households in Ireland, like most developed nations, are heavily dependent on the car for many household activities. As of 2016, 20% of Ireland's greenhouse gas (GHG) emissions arose from the transport sector (CSO, 2018d), most of which is attributable to the private car. With this figure predicted to increase in the near future (EPA, 2018), there is now an urgent need to transition towards more sustainable mobility practices, including walking, cycling and public transport. The latest Census figures (CSO, 2018b) show that 58.5% of Irish people commute to work by car, with a higher dependence for females (64.7% versus 53.1% - see Figure 1).

Figure 1: Commuter Car and Bicycle Cycling Shares, by Year and Gender

Source: Author's calculation based on Central Statistics Office census data (downloaded from www.cso.ie)
Note: Data are based on population aged 15 and over usually resident in the State at each census

While cycling participation rates in Ireland have been increasing rapidly since 2006 (Figure 1), they are considerably lower than the mid 1980's. Furthermore, the gender balance of cyclists has changed – in the 1986, female participation was higher than male (6.1% versus 5.4%). By 2016, just 1.7% of females cycled to work (versus 3.9% for males). Within the Dublin region (the focus of this paper), cycling is more prominent (7.6% overall), but females are again underrepresented and account for roughly one in four bikes on the roads (CSO, 2018c). The underrepresentation of women is common in many countries with low overall cycling rates, such as the US, UK, New Zealand and Australia (Winters and Zanotto, 2017).

Under the Irish National Cycle Policy Framework (Department of Transport, 2009), it was planned that 10% of all trips in Ireland would occur by bicycle by 2020. While incentives such as shared bike schemes in major cities and "Bike-to-Work" tax relief have helped to promote cycling, there is clearly considerable work to be done if these targets are to be achieved. This paper follows calls for more targeted efforts to increase female cycling rates in Ireland (Caulfield, 2014). We examine the factors that impact both female and male cycling rates and contribute to a better understanding of the barriers that currently exist. Following much of the literature, our analysis focuses on the effect of cycling infrastructure, controlling for a large range of structural, geospatial and demographic factors.

The Dublin region has a relatively extensive cycle network, with lanes of varying quality being distributed throughout the four local administrative authority areas. While much of this infrastructure has been constructed within the last ten to fifteen years, the quality of cycle lanes varies considerably across the region. Significant gaps in the network, lack of continuity in cycle lanes, loss of priority to other modes of transport at junctions, and insufficient lane widths that make overtaking difficult, have all been identified as factors that may impact the quality of the user's experience (National Transport Authority, 2013). In addition to issues regarding the quality of the infrastructure, a large proportion of the region's cycling network is located outside of the urban core of the city and follows orbital routes between suburban areas rather than directly linking these areas to the city centre.

This paper contributes to the small body of revealed preference analysis in this field. To our knowledge, this is only the second paper to combine complete census data with cycling infrastructural network data. Furthermore, we control for a considerably wider range of factors which affect cycling participation, many of which have not been tested using revealed preference data before. Our results have a direct impact on policy to promote cycling rates in Ireland and abroad. The paper is structured as follows: Section 2 discusses the main findings from previous literature; Section 3 presents the methods and datasets, with a particular focus on the quantification of cycling infrastructure; Section 4 presents the results; Sections 5 discusses policy implications.

2 Literature Review

Horton (2016) discusses an important emotional barrier to cycling: fear. He describes this emotion on many levels beyond the obvious fear of having a bicycle-related accident. These include the fear of being 'on view', of appearing 'inept' (leading to embarrassment and humiliation), of the physical exertion of cycling, and of undermining one's identity by travelling on a 'gendered, classed, raced and stigmatised vehicle'. Such fears are likely culturally embedded, and therefore difficult to overcome. However, much of the empirical literature has focused on the participation effects of cycling infrastructure which may reduce rates and fears of accidents within the current and potential cycling populations.

For example, Pucher et al. (2011) describe infrastructural improvements as an important driver of the growth in cycling in cities in the US and Canada from 1990. Furthermore, Pistoll and Goodman (2014), combine census data with cycling route density maps in Melbourne and also find positive effects. Other studies, however, are less supportive. Song et al. (2017) use a panel of commuters in three UK cities between 2010 and 2012 and do not find that proximity to infrastructure leads to a modal shift to either walking or cycling. Furthermore, the review of Heinen et al. (2010) finds no clear evidence of an optimal mix of cycling infrastructure for policymakers.

There are, however, many examples in the literature which suggest that safe cycling infrastructure is more important to women, which Garrard (2003) attributes to women being 'more risk averse'. Garrard (2003) describes such fears as inflated and biased (relative to actual risk of cycling), and also as an intergenerational barrier to cycling, in that parental fears prevent children from cycling.

Stated preference analysis (surveys, interviews and focus groups) are generally supportive of this higher risk aversion hypothesis. For example, in the US, Krizek et al. (2005) find that females are more likely to accept longer routes in exchange for higher safety. Furthermore, the surveys of Heesch et al. (2012) show that women are more likely to use off-road paths in Australia. The choice experiment of Sener et al. (2009) also shows that the amount of motorised traffic is the second most important consideration (after travel time) in route choice for commuter cyclists in Texas. However, while Garrard et al. (2006) find that the risks associated with sharing the road with vehicles is a barrier (based on focus groups and interviews), their survey results show that, amongst females who already cycle, safer routes are not chosen through the city of Melbourne.

Evidence from revealed preference studies are mixed. For example, in Canada, Winters and Zanotto (2017) perform an observational count study (2012 through 2014) and find no increase in the female share of cyclists during a period of expanded and upgrading cycling routes. Contrary to this, Garrard et al. (2008) use count data from 15 locations in Melbourne and conclude that females prefer safer off-road paths.

Beyond cycling infrastructure, Heinen et al. (2010) summarise the main motivations and barriers to cycling. Unsurprisingly, a natural environment which increases the discomfort of travelling by bike, such as steep hills and poor weather (rain, in particular), leads to lower cycling shares in both genders. For females, Aldred et al. (2017) highlight that winter conditions, the need to carry items, and hills are further barriers. In Australia, Garrard et al. (2006) also find that lack of confidence, low cycling skills and lack of fitness are impediments. In terms of the built environment, factors which reduce journey distance, such as high density development and road networks, promote cycling. Howard and Burns (2001), Sener et al. (2009), Heinen et al. (2010) and Pistoll and Goodman (2014) show that this is particularly prevalent for females. For commuters, bike-compatible workplaces, which include safe bike parking, showers, changings facilities and lockers, encourage more people to choose to cycle (Heinen et al., 2010). Finally, Pucher and Buehler (2008) explore policy mechanism in place to promote cycling in the Netherlands, Denmark and Germany (both genders). They find that bicycle parking, integration with public transport and training/education promote participation. However, they also highlight high participation in these countries may be the result of the very high cost of car ownership.

3 Data and Methods

3.1 Study Area

This research explores the factors that account for differences in female and male cycling rates for commuter trips, specifically taking advantage of commuting data collected as part of the Irish national census of 2016 (CSO, 2018b) combined with cycling network survey for Dublin in 2013 (National Transport Authority, 2018). Our unit of observation is the electoral district (ED) and our primary variable of interest is the percentage of adults aged 18-64 years that cycle to work by gender (termed the "cycling share" below).

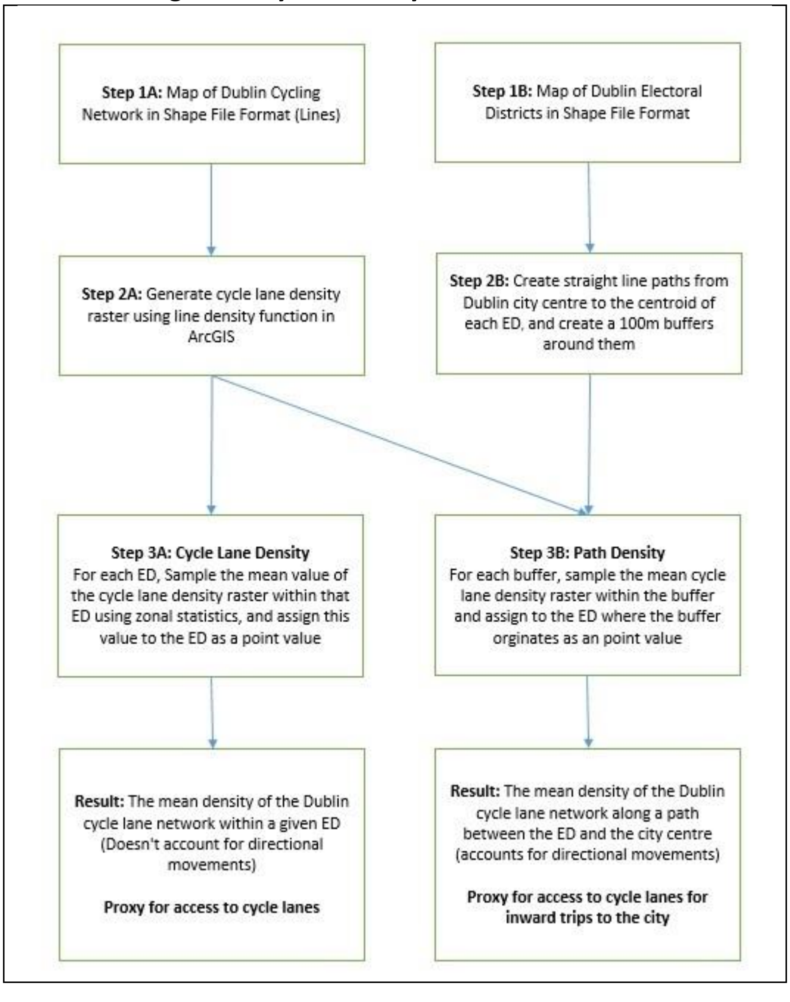
As this study is interested in the factors that impact on the modal share of cycling for commuter trips, not all locations within the Dublin region are considered for analysis. Specifically, all electoral districts with a centre point that fell outside a ten kilometre radius of Dublin city centre are excluded as, in general, these areas are rural and cycling participation rates are very small. In addition, EDs with centre points within two kilometres of the city centre are also excluded as the assumptions regarding direction of travel (inwards towards the centre) can't be considered to be valid once within the city centre. After these exclusions, the final sample size is 213 EDs (containing 503,617 individuals aged between 18 and 64 years, representing 17% of the national population).

3.2 Cycling Infrastructure Variables

Given the prominence of the role of infrastructure in understanding differences in male and female cycling shares, special emphasis is placed upon accounting for the quality of cycle lanes. To this end, we combine the National Transport Authority's (NTA) publically available GIS shape files which outlines the cycling network in the Greater Dublin Area in 2013 (National Transport Authority, 2018) with the ED boundary shape files available from the CSO's website (CSO, 2018a). Due to the fragmented nature of the Dublin cycling network, and issues associated with matching the datasets available, a precise network analysis in ArcGIS is not possible. Instead, we calculate cycle lane density within each ED and treat that as a proxy for access to safer cycle routes.

Figure 2 describes the steps undertaken to construct the lane density variables. The cycle "lane density" variable (within each ED) is estimated by creating a cycle lane density raster (pixel grid) using the line density function in ArcGIS based upon the Dublin cycling network shape file, where each pixel in the raster is assigned a value based on the density of cycle lanes in proximity to it. The mean value of the raster pixels within the boundary of a given ED, as defined by the ED shape file, is then calculated using the zonal statistics function in ArcGIS assigned to the ED as a continuous variable. This approach has been previously used in comparable studies of modal share in Australia (Pistoll and Goodman 2014). Figure 3 (left panel) presents an overview of how these ED-specific values relate to the underlying network. The values calculated for the lane density for each ED should be treated as relative values within this study, and are best understood when comparing the density of cycle lanes between EDs, rather than with any external datum, with higher values denoting a greater concentration of cycle lanes and lower values a lower concentration of cycle lanes.

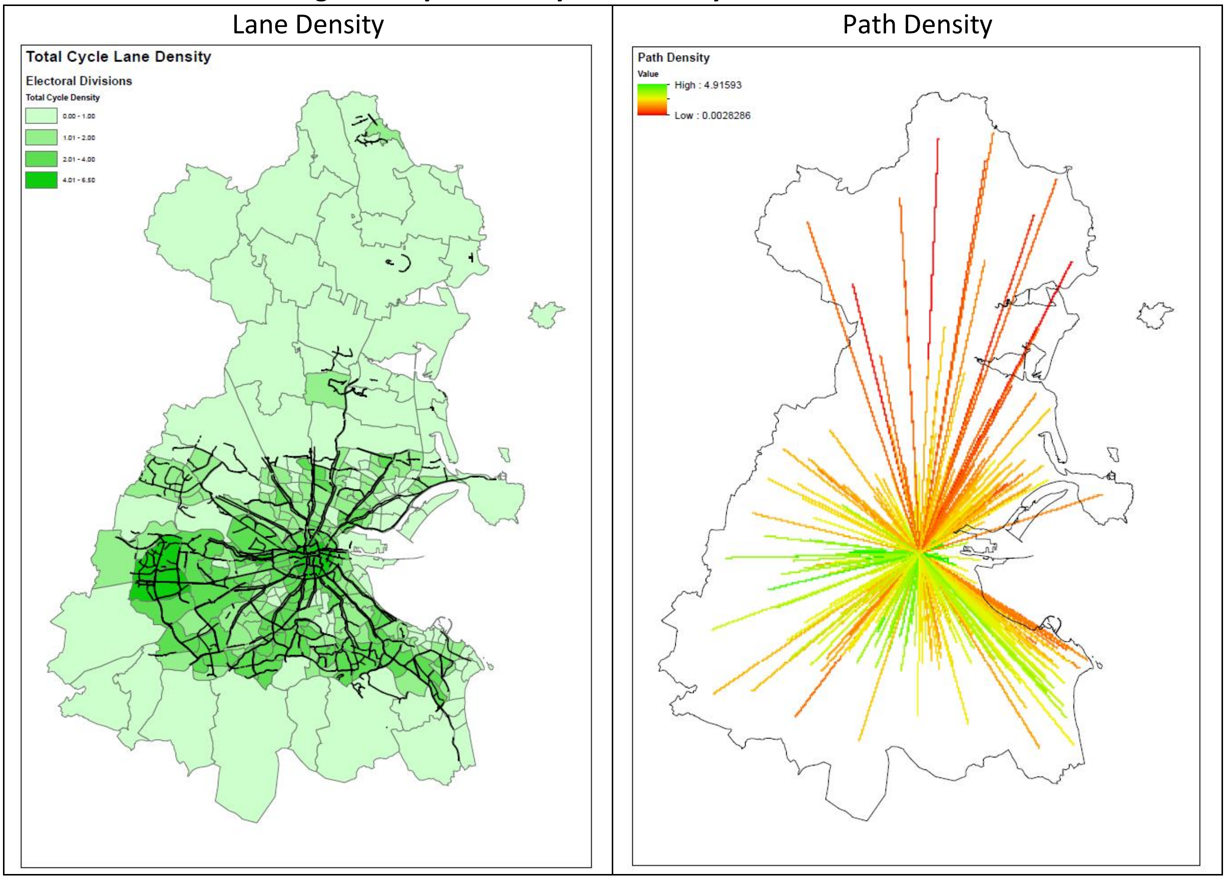
Figure 2: Cycle Density Variable Creation



We also attempt to account for the underlying direction of travel, where it is assumed that commuters are more likely to be travelling towards the city centre rather than moving equally in each direction. In this regard, a path density variable is calculated based upon the average value of the cycle lane density raster cells. To achieve this, a line is drawn from the centroid of each ED to the city centre with a buffer of 100 metres either side of each line. The mean value of the cycle lane density raster mentioned previously is then calculated for each buffer and assigned to the ED where its origin lay. Therefore, a buffer that passed through areas with a higher density of cycle lanes would be assigned a higher value than one that passed through areas with lower values. As with the cycle lane density variables, these values should be treated as relative scores and should only be interpreted in terms of relative magnitude rather than absolute values with regard to an external datum.

Figure 3 outlines the distribution of this variable across the area under examination (right panel). Due to the complex nature of real world route choices, these variables must be considered proxies for the access of a given ED to cycle lane infrastructure for all travel, and specifically for trips to the city centre.

Figure 3: Cycle Density Variables by Electoral District



Notes: “Lane Density” measures cycle lane coverage on roads within each electoral district. “Path Density” measures cycle lane coverage between an electoral distric centriod and the city centre centroid (on straight lines)
Source: Author’s calculations using the National Transport Authority’s cycle network survey in 2013

3.3 Additional Variables for Analysis

Other independent variables for the models are created using census data. Previous literature has outlined a number of factors which are correlated with the decision to cycle, including education (Avila-Palencia et al., 2017), the presence of children (Aldred et al., 2017) and nationality (CSO, 2018c). However, given the depth and completeness of our data, we have the opportunity to explore a number of new hypotheses. First, we expect that cycling is more difficult for those living in apartments (measured as the share of apartment dwellers in an ED). Communal bicycle storage facilities in most apartment buildings in Dublin city is lacking, and the inconvenience associated with transporting a bicycle from the building entrance to the individual's apartment may be high. This is motivated the findings of Heinen et al. (2010) who find that secure, safe bicycle parking is an important driver of participation. We also expect that EDs with higher shares of healthy individuals will have higher cycling shares, primarily because commuting by bike requires a higher level of physical effort relative to other modes of transportation, particularly as distance increases. Table 1 provides an overview of all variables employed.

Table 1: Descriptive Statistics for all Variables in Regression Sample [N = 213]

Variable Name	Description	Mean	SD	Min	Max
Female Cycling Share	The percentage of female commuters that cycle	5.1%	3.4%	0.2%	17.2%
Male Cycling Share	The percentage of male commuters that cycle	11.7%	4.7%	3.1%	26.8%
Lane Density	The density of cycle lanes within a given ED	1.8	0.9	0.0	5.3
Path Density	Cycle density field intersected by a line from the ED centroid to Dublin city centre	2.2	0.8	0.6	5.7
Stated Health (Female)	The percentage of females within an ED with stated "good" or "very good" health	58.3%	7.0%	43.5%	76.9%
Stated Health (Male)	The percentage of males within an ED with stated "good" or "very good" health	59.6%	6.9%	34.8%	76.7%
Education (Female)	The percentage of females within an ED with an Irish level 8 qualification or above	28.9%	16.3%	2.4%	64.1%
Education (Male)	The percentage of males within an ED with an Irish level 8 qualification or above	29.1%	18.6%	1.2%	67.1%
Distance to Centre	The straight line distance between the centroid of an ED and the centre of Dublin city centre	5.8	2.1	2.0	9.9
Children	The percentage of households with children (married plus cohabiting) divided by total households	28.7%	8.1%	9.4%	53.4%
Professionals (Female)	Combined share female professional, managerial, and non-manual shares in each ED as a percentage of total workers	62.0%	15.8%	24.0%	85.1%
Professionals (Males)	Combined share male professional, managerial, and non-manual shares in each ED as a percentage of total workers	52.1%	16.6%	17.5%	82.9%
Apartments	The flat/apartment share of houses within a given ED	19.9%	18.8%	0.0%	97.1%
Nationality	The proportion of individuals within an ED born outside Ireland	13.1%	8.1%	3.3%	49.2%

Source: own calculations using Irish Central Statistics Office 2016 census data
Notes: unit of observation is the electoral district. Regression sample consists of electoral districts between two and ten kilometres of city centre. "SD" stands for standard deviation.

3.4 Modelling Approach

We adopt a simple Ordinary Least Squares (OLS) regression modelling approach. For both models, the dependent variable is either the percentage of commuting females or males that cycle. This can be considered to be the mode share of cyclists within the respective commuter population. The modelling approach is described in Equation 1:

$$Y_i = \beta_0 + \sum_{P=1}^{P} \beta_p X_{ip} + \varepsilon_i \qquad (1)$$

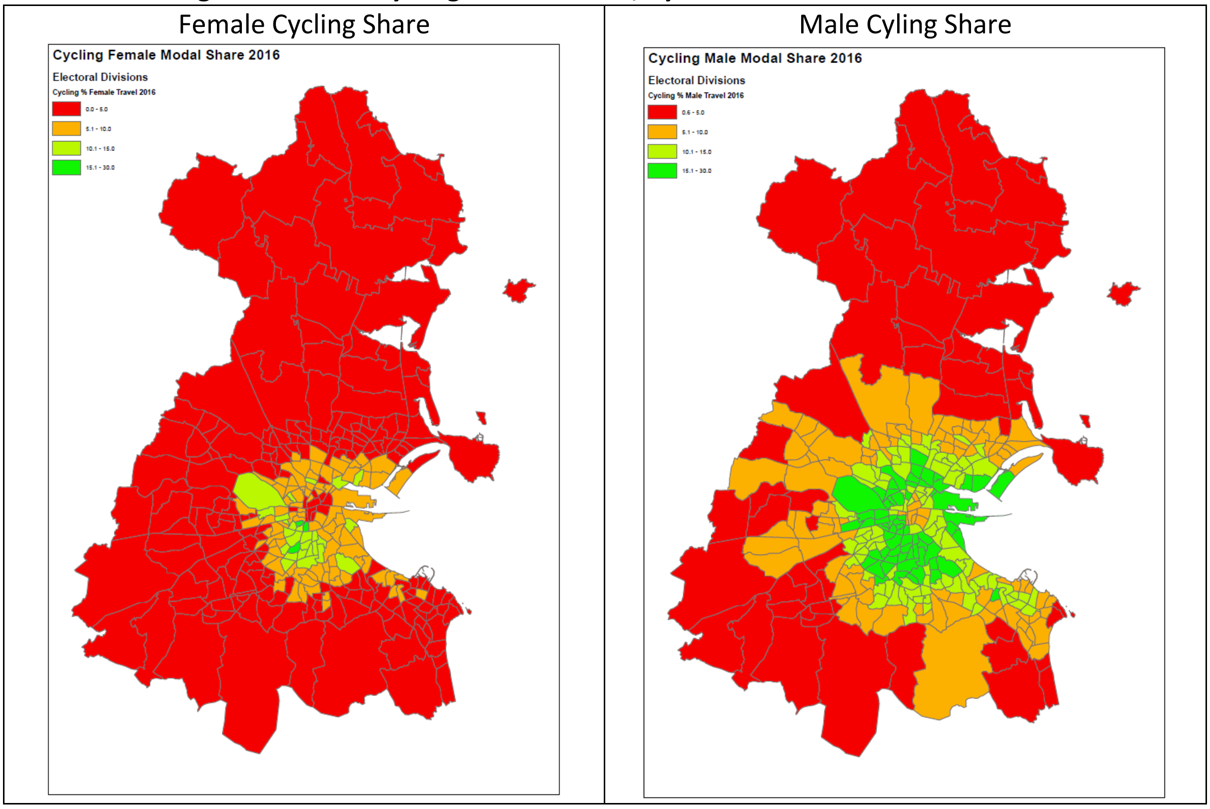
where: Y_i is the dependent variable, β_0 is the intercept, β_p is the coefficient of the independent variables, X_{ip} is the observed value, and ε_i is the error term.

4 Results

4.1 Geographic Distribution of Cycling by Gender

Figures 4 provides an outline of the geographic distribution of cycling by gender throughout the Dublin region (females on left panel, and males on right). Both maps clearly outline the concentration of cycling share within the inner suburbs of the city, with much lower rates as distance from city increases. As these figures use the same colour coding and scaling, it is possible to make a direct comparison between the distribution of cycling shares within the male and female commuting populations. It is clear that the modal share of cycling is both smaller and more geographically concentrated for females compared to males, with female rates of cycling decline more sharply as distance from the city centre increase.

Figure 4: Dublin Cycling Share in 2016, by Electoral District and Gender



Source: own calculations using Irish Central Statistics Office 2016 census data

4.2 Regression Results

Table 2 outlines the OLS regression results for female and male cycling shares. We estimate two sets of models: in Model 1, we include the density of cycle lanes within a given ED acting as a proxy for cycle safety ("Lane Density"); in Model 2, we use the path density variable which accounts for lane density on a straight line between the centroid of the ED and the city centre ("Path Density"). The regressions are weighted by ED share sample population. Both safety variables are modelled using dummy variables, splitting the sample into even tertiles – low, medium and high. EDs in the lowest safety tertile are used as the reference variable in both cases. In all models, we divide the dependent variable (cycling share) by its mean so that male and female coefficients are directly comparable as percentage changes in the cycling share. In terms of the overall model performance, we observe R-squared values ranging between 0.759 and 0.803.

Following the literature, our key variable of interest is the role of infrastructure in the decision to choose to cycle. The results of Model 1 indicate that the density of cycle lanes within a given ED is not statistically significant for either males or females in Dublin, suggesting that increased cycle lane infrastructure is not directly linked to increased levels of cycling participation. Furthermore, in Model 2, we see a similar non-significant result – the density of cycle paths between the ED and the city centre has no effect of participation (possible reasons for this insignificant result, are discussed in the next section).

The majority of our non-infrastructure explanatory variables are significant and of the expected sign (the remainder of this section focuses on Model 1 results as there is no significant difference between Model 1 and 2 for these variables). The distance from the centroid of a given ED to the centre of Dublin is strongly and negatively correlated with cycling shares for both genders – for example, relative to the first quartile, the female cycling shares in quartiles two, three and four are 43%, 70% and 86% lower, respectively. Consistent with Figure 4, this negative relationship between cycling rates and distance is stronger for women than for men (27%, 50% and 66% lower for males). We also find that EDs with higher share of individuals living in apartments have lower cycling shares. This relationship is much stronger for females, where a one percentage point (PP) increase in the apartment share decreases the female cycling share by 8.7% (just 0.3% for males). If our hypothesis on apartments is causally correct, the costs of keeping a bicycle in apartments without communal bicycle facilities is considerably higher for females.

In terms of ED characteristics and demographics, the results of both models indicate that areas with higher levels of education have higher cycling shares. Again, this effect is very strong for females – a PP increase in the share of females with higher education increases the cycling share by 3.3% (compared to just 0.6% in the male model). For children, the effects are similar across genders, and a PP increase in the share of households with young children decreases the cycling share by about 1%. Interestingly, stated health variable was found to be significant for males only, and areas with higher shares of individuals in "good health" (self-reported) have higher cycling shares. The different results for health by gender may be due to the higher commuting distances of male cyclists and therefore the higher physical effort and minimum level of health required. Employment status only affects female participation, and a PP increase in the share of female higher professionals decreases the female cycling share by 0.8%. Finally, and contrary to previous results in Ireland, we find no nationality effect for nationality – EDs with higher shares of individuals born outside Ireland have the same cycling shares.

Table 2: OLS Results for Cycling Share Model

	Model 1: Lane Density		Model 2: Path Density	
	Female Cycling Share	**Male Cycling Share**	**Female Cycling Share**	**Male Cycling Share**
Lane Density Low	----------- *reference category* -----------			
Lane Density Med	-0.0375 (-0.66)	-0.0342 (-0.9)		
Lane Density High	-0.00179 (-0.03)	-0.0146 (-0.41)		
Path Density Low			----------- *reference category* -----------	
Path Density Med			0.0316 (0.56)	0.00239 (0.06)
Path Density High			0.0178 (0.29)	0.0267 (0.63)
Distance Quartile 1	----------- *reference category* -----------		----------- *reference category* -----------	
Distance Quartile 2	-0.425***(-5.46)	-0.268*** (-5.32)	-0.421*** (-5.01)	-0.269*** (-4.86)
Distance Quartile 3	-0.703***(-8.06)	-0.5*** (-8.98)	-0.710*** (-7.74)	-0.516*** (-8.68)
Distance Quartile 4	-0.864*** (-9.41)	-0.663*** (-11.27)	-0.864*** (-8.82)	-0.666*** (-10.47)
Education	0.0328*** (5.38)	0.00627** (2.16)	0.0301*** (4.91)	0.00714** (2.40)
Stated Health	-0.00820 (-0.79)	0.0113** (1.90)	-0.00476 (-0.46)	0.0094** (1.53)
Children	-0.00978* (-1.53)	-0.0118*** (-3.17)	-0.00948* (-1.48)	-0.0094*** (-2.45)
Apartments	-0.0866*** (-3.47)	-0.0025*** (-1.59)	-0.00851***(-3.25)	-0.0023*** (-2.45)
Professionals	-0.00779* (-1.96)	-0.000585 (-0.25)	-0.00708* (-1.75)	-0.00154 (-0.64)
Nationality	-0.00115 (-0.22)	-0.005 (-1.5)	-0.00105 (-0.20)	-0.0061 (-1.76)*
Constant	1.979*** (4.38)	0.998*** (3.62)	1.752*** (3.81)	1.067*** (3.83)
N	213	213	205	205
R Squared	0.803	0.798	0.759	0.759

Source: own calculations using Irish Central Statistics Office 2016 census data

Notes: t-statistics in parentheses and statistical significance denoted by * (p<0.10), ** (p<0.05) and *** (p<0.010).

5 Discussion

The results describe the role of various geographic, infrastructural, and socio-economic variables in terms of predicting cycling shares within the male and female commuter populations in Dublin. Our key variable of interest – cycling infrastructure – accounts for the provision of cycle lanes. In this regard, we used both lane density within an ED and path density between ED and the city centre (the latter to account for directional effects). However, and contrary to the expectation that areas with safer routes to the city would have higher cycling shares, we find no effect for either gender. While it must be acknowledged that these infrastructural variables are proxies for access to safe cycle routes, (representing the density of cycle lanes rather than either objective or subjective safety on a specific point-to-point route) the methods used are similar to those of (Pistoll and Goodman, 2014), who found a positive effect.

The results of this analysis therefore raise important questions regarding the effectiveness of the current implementation and provision of cycling infrastructure within an Irish context with regard to meeting stated goals of increased cycling participation, as outlined in national policy documents. While many cycle lanes, especially those located in south and west Dublin are relatively new, our findings raise concerns as to whether the provision of cycle lanes in their current form are meeting the needs of potential new cyclists and providing access to the key employment areas within the city. In this regard, the consistency of point-to-point cycling infrastructure could be key for increasing participation. For example, while the number of cycling lanes in Dublin is increasing, many routes throughout the city have less than complete coverage. It may be the case that cycling infrastructure needs to be (largely) unbroken between departure and arrival points to increase participation. This is supported by previous research (Sener et al., 2009).

With regard to distance, both the descriptive statistics and the regression models show that the negative effect of longer commutes is more pronounced for females. These results suggest that females have a reduced cycling range for commuter trips compared to males, and highlight commute distance as a potential barrier to increased cycling modal share within the female population. In this regard, policies which could reduce “distance” would likely be beneficial. For example, electric bikes reduce the effort involve in commuting by bicycle and could be subsidised further. However, we note that the stronger negative distance effects for females may not be due to underlying strength/health/fitness differences, but could be due to differences in workplace expectations regarding personal appearance (Peluchette et al., 2006, Peluchette and Karl, 2007, Gurung et al., 2018). It may be the case that the lack of workplace changing and showering facilities in Ireland is the underlying driver of our distance results. Such facilities, which include showers, storage and lockers, have been shown to be very important in driver cycling participation in many countries (Garrard et al., 2006, Heinen et al., 2010)

We also find that areas with higher shares of apartments have lower cycling shares, and this effect is particularly strong for women. Our proposed mechanism for this relationship is that there is a personal, non-monetary cost of storing a bicycle in an apartment block that has no communal bicycle facilities (bringing a bicycle from the apartment block entry point to the individual’s apartment). If this hypothesis is correct, our results imply that this cost is higher for women. The policy response would be to ensure that all apartment blocks have a convenient and safe location for tenants to keep their bicycles.

There are a number of other important variables which deserve attention. Education is a key determinant of cycling. However, we are unsure as to the underlying mechanisms of this relationship, but this could be related to higher environmental concern and knowledge of the costs of other modes. The presence of children is also correlated with decreased levels of cycling (also observed in Ryley (2006)). We expect that this is due to the additional transport burdens arising from children that cannot be adequately addressed by cycling, at least within the current Irish transport landscape. Furthermore, the proportion of professionals working within an ED is negatively related to female cycling shares only, which again could be related to workplace expectations imposed on this group.

6 Conclusions

This research was undertaken to examine the factors that impact the discrepancy in observed cycling participation between males and females within the Dublin region of Ireland, which we have called the gender-cycling-gap. Specific focus was put upon the role of factors such as access to cycling infrastructure. However, based on the two density metrics used, no such relationship could be identified.

A large number of controls are important drivers of participation. For example, distance to the city centre is an important factor affecting the proportion of both males and females who commute to work. However, females appear to be more sensitive to distance than males, and the issue of range within the female population may be acting as a barrier to large-scale adoption of cycling as a means of reducing car journeys. We also find that apartment tenants are less likely to cycle, particularly in the case of female commuters. Other important correlates are education (positive), good health (positive for males only), the presence of children (negative) and higher-professional status (negative for females only).

From a policy perspective, we have highlighted the promotion of electric bikes to reduce "distance" for females. Furthermore, the provision of secure communal bicycle facilities in all apartment blocks may increase the female cycling share. While not formally tested, the findings for distance and professional status might be related to workplace's expectations imposed on females, which could be less acute for men. The provision of changing facilities in workplaces could alleviate this problem, if this is indeed the underlying mechanism.

These results raise one significant question regarding the further promotion of cycling as a mode of sustainable commuting, namely: why is the current provision of cycling infrastructure, specifically in an Irish context, not correlated with higher rates of cycling? It is indeed counterintuitive that safer roads are not utilised more. However, breaks in the network could be key to participation, and from a commuter's perspective, the appraisal of infrastructural quality may be binary (complete or non-complete) rather than continuous. However, we also note that our infrastructural variables are to be considered as proxies. The data does not allow to quantify the quality of cycle lanes between exact departure and arrival points with exact precision.

References

ALDRED, R., ELLIOTT, B., WOODCOCK, J. & GOODMAN, A. 2017. Cycling provision separated from motor traffic: a systematic review exploring whether stated preferences vary by gender and age. *Transport reviews,* 37**,** 29-55.

AVILA-PALENCIA, I., DE NAZELLE, A., COLE-HUNTER, T., DONAIRE-GONZALEZ, D., JERRETT, M., RODRIGUEZ, D. A. & NIEUWENHUIJSEN, M. J. 2017. The relationship between bicycle commuting and perceived stress: a cross-sectional study. *BMJ open,* 7**,** e013542.

CAULFIELD, B. 2014. Re-cycling a city–Examining the growth of cycling in Dublin. *Transportation research part A: policy and practice,* 61**,** 216-226.

CSO. 2018a. *Census 2016 Boundary Files* [Online]. Available: https://www.cso.ie/en/census/census2016reports/census2016boundaryfiles/ [Accessed 21/12/2018].

CSO. 2018b. *Census of Population 2016* [Online]. Available: https://www.cso.ie/px/pxeirestat/statire/SelectTable/Omrade0.asp?Planguage=0 [Accessed 21/12/2018].

CSO. 2018c. *Census of Population 2016 – Profile 6 Commuting in Ireland* [Online]. Available: https://www.cso.ie/en/releasesandpublications/ep/p-cp6ci/p6cii/p6mtw/ [Accessed 21/12/2018].
CSO. 2018d. *Environmental Indicators Ireland 2018* [Online]. Available: https://www.cso.ie/en/releasesandpublications/ep/p-eii/eii18/greenhousegasesandclimatechange/ [Accessed 21/12/2018].
DEPARTMENT OF TRANSPORT. 2009. *National Cycle Policy Framework* [Online]. Available: http://www.smartertravel.ie/content/national-cycle-policy [Accessed 21/12/2018].
EPA. 2018. *Ireland's 2018 Greenhouse Gas Emissions Projections* [Online]. Available: www.epa.ie/pubs/reports/air/airemissions/ghgprojections2017-2035/2018_Seminar_GHG_Projections_to_2035.pdf [Accessed 21/12/2018].
GARRARD, J. 2003. Healthy revolutions: promoting cycling among women. *Health Promotion Journal of Australia,* 14**,** 213-215.
GARRARD, J., CRAWFORD, S. & HAKMAN, N. 2006. *Revolutions for Women: Increasing women's participation in cycling for recreation and transport (Executive Summary)* [Online]. Available: www.researchgate.net/publication/270762722_Revolutions_for_Women_Increasing_women's_participation_in_cycling_for_recreation_and_transport_Executive_Summary [Accessed 20/12/2018].
GARRARD, J., ROSE, G. & LO, S. K. 2008. Promoting transportation cycling for women: The role of bicycle infrastructure. *Preventive Medicine,* 46**,** 55-59.
GURUNG, R. A. R., PUNKE, E., BRICKNER, M. & BADALAMENTI, V. 2018. Power and provocativeness: The effects of subtle changes in clothing on perceptions of working women. *The Journal of Social Psychology,* 158**,** 252-255.
HEESCH, K. C., SAHLQVIST, S. & GARRARD, J. 2012. Gender differences in recreational and transport cycling: a cross-sectional mixed-methods comparison of cycling patterns, motivators, and constraints. *International Journal of Behavioral Nutrition and Physical Activity,* 9**,** 106.
HEINEN, E., VAN WEE, B. & MAAT, K. 2010. Commuting by Bicycle: An Overview of the Literature. *Transport Reviews,* 30**,** 59-96.
HORTON, D. 2016. Fear of cycling. *Cycling and society.* Routledge.
HOWARD, C. & BURNS, E. 2001. Cycling to work in Phoenix: route choice, travel behavior, and commuter characteristics. *Transportation Research Record: Journal of the Transportation Research Board***,** 39-46.
KRIZEK, K. J., JOHNSON, P. J. & NEBIYOU TILAHUN. Gender differences in bicycling behavior and facility preferences. Conference Proceedings: Research on Women's Issues in Transportation, 2005 Chicago, Illinois. 31-41.
NATIONAL TRANSPORT AUTHORITY. 2013. *Greater Dublin Area Cycle Network Plan* [Online]. Available: https://www.nationaltransport.ie/publications/strategic-planning/gda-cycle-network-plan/ [Accessed 21/12/2018].
NATIONAL TRANSPORT AUTHORITY. 2018. *GDA Cycle Network Survey 2013* [Online]. Available: https://data.gov.ie/dataset/cycle-network-survey [Accessed 21/12/2018].
PELUCHETTE, J. V. & KARL, K. 2007. The impact of workplace attire on employee self-perceptions. *Human Resource Development Quarterly,* 18**,** 345-360.
PELUCHETTE, J. V., KARL, K. & RUST, K. 2006. Dressing to impress: Beliefs and attitudes regarding workplace attire. *Journal of Business and Psychology,* 21**,** 45-63.
PISTOLL, C. & GOODMAN, A. 2014. The link between socioeconomic position, access to cycling infrastructure and cycling participation rates: An ecological study in Melbourne, Australia. *Journal of Transport & Health,* 1**,** 251-259.
PUCHER, J. & BUEHLER, R. 2008. Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany. *Transport Reviews,* 28**,** 495-528.

PUCHER, J., BUEHLER, R. & SEINEN, M. 2011. Bicycling renaissance in North America? An update and re-appraisal of cycling trends and policies. *Transportation Research Part A: Policy and Practice,* 45**,** 451-475.

RYLEY, T. 2006. Use of non-motorised modes and life stage in Edinburgh. *Journal of transport geography,* 14**,** 367-375.

SENER, I. N., ELURU, N. & BHAT, C. R. 2009. An analysis of bicycle route choice preferences in Texas, US. *Transportation,* 36**,** 511-539.

SONG, Y., PRESTON, J., OGILVIE, D. & CONSORTIUM, I. 2017. New walking and cycling infrastructure and modal shift in the UK: A quasi-experimental panel study. *Transportation research part A: policy and practice,* 95**,** 320-333.

WINTERS, M. & ZANOTTO, M. 2017. Gender Trends in Cycling over Time: An Observational Study in Vancouver, British Columbia. *Journal of Transport & Health,* 5**,** S37-S38.