Urban connectivity and female labour force participation

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1 Introduction

It is well-accepted that the built form of urban space has significant effects on the lives of its inhabitants. The material dimension of the city – for instance, its density – shapes economic, environmental, and social factors (Harari, 2020; Stone Jr, 2008; Bramley et al., 2009; Marshall et al., 2014). But these effects are not even; urban space and the experiences of it are gendered. Feminist critiques of urban planning have demonstrated how planning has favoured men at the expense of women's autonomy, safety, and access to opportunities. Urban space has been dichotomized as public and private, with the urban city viewed as masculine while the residential suburbs are viewed as the domain of women (Saegert, 1980). This notion that women belong to the home is deep-rooted, and has informed divisions of space along gender lines in various societies, irregardless of density or economic systems (McDowell, 1983). The gender division of space has been rendered "brick and concrete" through the built form, which in turn reinforces patriarchal social roles (Markusen, 1980). The effect of this division has been studied in the context of transportation, which provides women with a gateway into the male domain of urban public life (Dunckel-Graglia, 2013). Transit systems tend to plan for car-centric single trips from the urban fringes into the downtown core, a typically male pattern of use that conflicts with women's trip-chaining behaviour (Perez, 2019). The implicit male default of public transit is also highlighted in women's experiences of sexual violence, spurring the adoption of women-only transit in some countries (Dunckel-Graglia, 2013).

The governance of urban space affects the location of production sites, like factories or offices, and also determines the transportation networks that allow employees to move between home to work (Markusen, 1980). As such, urban mobility, complicated by transit systems and spatial form, is important for economic participation. In particular, the suburbanization of North American cities in the late 20th century has posed a challenge to women's economic participation. In a society where women are expected to do the uncompensated work of social reproduction – "the direct provision of the conditions of physical and mental health, cooked meals, personal services, education, maintenance of living conditions and child care" (Markusen, 1980) – as well as waged labour to support household expenditure, the spatial alienation between home and work is a source of friction. As England (1991) describes, "the form of the urban spatial structure which worked for women who were full-time suburban homemakers simply does not work for women helping to finance as well as

maintain the suburban home." This raises the question of how urban connectivity mediates women's economic participation.

Building compact and connected urban developments has increasingly become the answer to combat the adverse environmental effects arising from urban sprawl. The United Nations New Urban Agenda suggests that "accessible and well-connected infrastructure and services, sustainable population densities and compact design and integration of new neighbourhoods into the urban fabric" should be pursued to mitigate urban sprawl and social marginalization (United Nations, 2016). While density has been a popular measure for urban sprawl/compactness, it does not fully capture the spatial form of the city. To understand how urban processes play out in the city, it is important to scrutinize the "infrastructure that permeates all its functions" (Star, 1999). Thus, I turn our attention to the street network, which prescribes the space of possibilities for transportation systems that connect home and work. Street networks are effectively permanent, and urban development is occurring around the world at a rapid pace, with 68% of the world's population projected to live in urban areas by 2050 (United Nations, 2018). In light of these facts, decisions made about the development of new street networks will have lasting consequences. Beyond environmental sustainability, it is worth considering how street networks can affect gendered experiences of urban life, especially in terms of economic participation.

This paper will contribute to the emerging body of empirical work on the effects of spatial form, with particular attention on an under-appreciated aspect of the city: street network connectivity. I evaluate the claim made by feminist scholars that the present spatial form of urban regions is unsuitable for women, by asking three questions. Firstly, are there gender differences in commuting behaviour? Secondly, does street network connectivity affect commuting behaviour? Finally, what is the relationship between street network connectivity and women's labour force participation (LFP)? I hypothesize that more connected urban areas will have higher rates of female LFP, due to greater accessibility of waged labour opportunities. Recognizing that feminist critiques of urban planning has focused on the North American context, this paper studies the relationship between urban connectivity and LFP rates in Canada, using data from the 2016 Canadian Census and from Barrington-Leigh and Millard-Ball's aggregation of the Street Network Disconnectedness Index (SNDI).

Subsequently, Section §2 in this paper reviews the literature on the gender division of work and urban space, the determinants of LFP, and the effects of spatial form. section §3 defines the research questions that this paper will answer, and section §4 describes the data and methods used. Next, Section §5 and Section §6 describes the results and offers some analysis on gender differences in commuting behaviour and how street network connectivity affects female LFP respectively. Finally, Section §7 concludes.

2 Literature Review

2.1 Work, gender, and urban space

The distinctions between work and home, urban and suburban, and production and reproduction that pervade urban planning have come under scrutiny by feminist scholars. These distinctions presume an ideal married heterosexual nuclear family, wherein the husband is the

sole breadwinner and their wives stayed at home to manage the children and the household (Hayden, 1980). The Fordist era saw the height of this spatial division between specialized reproduction in suburban homes and specialized production in the city (England, 1991). Located far away from the factories and offices of the city, the realm of detached, two- or three-bedroom dwellings in the suburbs was an escape for the male worker from the toil of production (McDowell, 1983). At home, the male breadwinner enjoyed the conspicuous consumption of his wife's labor, his wage earnings justifying his position of power in a patriarchal organization of the household (Markusen, 1980). Zoning impeded women's access to shared community spaces that could alleviate their burdens of housework and childcare, thereby ensuring that social reproduction fully occupied women's time (Hayden, 1980).

However, Fordism also ushered in an era of advertising and mass consumption. While households retreated into newfound private spaces, they also were pressured to conform through consumption (Hayden, 1980). Home ownership became an ideal to aspire towards, and along with this came the encouragement to populate the home with a dazzling array of appliances (Hayden, 1980). Women, especially, were targeted by advertisers with the promise that the new electrical appliances could aid them in their domestic work (McDowell, 1983). This, and the variety of choice in what women could buy, appeared to be empowering (McDowell, 1983). However, the maintenance demanded by consumerism at home continued to constrain women to domestic work (Hayden, 1980). At the same time, the need for households to keep up with expenditures on homeownership, car ownership, and consumption goods harkened the entry of women into the paid labour force.

With the increased economic participation of women in waged labour in the 1970s and 80s, the dysfunction of contemporary "patterns of homeownership, real estate construction practices, and the permanency of urban physical structure" were made apparent (Markusen, 1980). Capitalism had spurred women's entry into waged labour, but it also relies on women's work in social reproduction. Insofar as they both require women's time, there is a conflict between the labour of social reproduction and production (Markusen, 1980). While it is not remunerated, the work of domestic social reproduction is invaluable to the functioning of capitalism in cities – women's prioritization of waged labour over domestic work thus threatens "the very logic of urban structure" (Castells, 1978). Even as women joined the labour force, patriarchal social roles still abounded, and employed women continued to disproportionately shoulder the burden of housework (Saegert, 1980). In addition to the time constraint, women are also geographically constrained by the spatial isolation of the suburbs, limiting their access to employment opportunities. Within households that own cars, men are more likely to have access to it, leaving women reliant on their husbands for mobility, or on inflexible and underdeveloped public transportation systems (England, 1991). This has the effect of subjugating women to a secondary labour force where only low-skilled and low-wage jobs are available (Markusen, 1980; Rutherford and Wekerle, 1988).

In sum, spatial form, especially in housing developments and zoning, have been an obstacle to women's autonomy. The assumption of the traditional nuclear family in urban governance has privileged men, while complicating the balancing act that women play between the multiple roles of mother, domestic manager, partner, and wage earner (England, 1991).

2.2 Determinants of female LFP

Female LFP has risen steadily around the world. In industrialized countries, this increasing trend began during the post-World War II era (Kamerman, 1979) and has continued to persist since (Jaumotte, 2004). In Canada, female LFP experienced a marked increase during the 1970s and 80s, but has since stagnated at about 70% (Beaudry and Lemieux, 1999). What factors explain the rise of female LFP? There are several approaches explaining the determinants of female LFP, namely structural, institutional, and cultural (Mansour, 2018). The structural approach highlights economic development as a critical component for women's increased LFP, especially in the effects of education and the emergence of white-collar work (Goldin, 1994), and sectoral transformation in the economy (Olivetti, 2013). The institutional approach considers the role of the state and policies, such as childcare provision, in alleviating women's social reproduction responsibilities which frees them in pursuing employment. Finally, the cultural approach points to changing attitudes about women's social roles and stigma towards certain types of work (Olivetti, 2013).

The determinants of female LFP are hard to pin down, and the determinants of female LFP vary from country to country. A vast body of work in economics studying female LFP has used explanatory variables including macroeconomic market conditions, income levels, policy instruments (such as tax incentives, childcare subsidies, child benefits, and paid parental leave), female education, cultural, social and religious attitudes and household characteristics (Jaumotte, 2004; Olivetti, 2013; Thévenon, 2013; Klasen et al., 2020). Work specific to the Canadian context includes the examinations of the relationship between female LFP and child presence, husband's income, education attainment (Spencer, 1973), child care policies (Powell, 1997), tax benefits (Tsounta, 2006), religiosity (Dilmaghani and Dean, 2016), age cohort effects (Beaudry and Lemieux, 1999), and Aboriginal status (White et al., 2003).

In urban studies, the importance of these factors in promoting gender equality in economic opportunity is acknowledged. For instance, Markusen (1980) proposes that solving the problem of child care is crucial to facilitating women's labour force participation. There is an institutional element to this, especially in the question of who child care should be provided by. Hayden (1980) notes that the solution thus far has been through private provisions, which can be problematic as this merely shifts the responsibility onto other working women (who are usually racialized and lowly paid). However, they highlight that the spatial element should not be overlooked; the provision of childcare is not sufficient, as the location of these services poses a fundamental problem too (Hayden, 1980). Focusing on institutional policies distracts from addressing the spatial structures that have created the need for them in the first place.

It is notable that urban form has been overlooked as a determinant for female LFP. The U-shaped female labour supply function (Goldin, 1994) is an influential economic model describing how female LFP has grown over time with economic development. Interestingly, the trough of the U-shaped function in the 1940s and the subsequent increase in female economic participation corresponds to urban theorists' explanations for the spatial subjugation of women, and their subsequent entry into waged labour in the North American context. The relationship between urban form and female LFP bears closer investigation.

2.3 Urban connectivity and street networks

The effects of urban form, especially housing, on gender equality are well understood by urban scholars. Both the layout within the home and residential zoning influence women's access to economic opportunity. Markusen (1980) insists that housing must become more diverse in answering the different needs that non-traditional households, such as single-parent families, might have. Hasell and Peatross (1990) note how the interior architecture of homes have changed with women's entry into the labour force, with kitchen spaces becoming more open and integrated with the rest of the home's space. And on a neighbourhood scale, Hayden (1980) points to several development pilots that deviate from the dichotomous construction of public and private by converting the land dividing suburban homes into community spaces. Furthermore, the integration of urban space, which can be achieved through greater urban connectivity, disrupts the gendered division of home and work. England (1991) spells out the relationship between urban form and gender that this paper seeks to investigate:

> Certainly, central cities, especially when compared with single family dwelling suburbs, have more accessible facilities and greater diversity of housing and services. Indeed, the central city is regarded as being potentially more supportive of women than low-density, homogeneous suburbs.

However, Hayden (1980) warns against pitting "city" against "suburb", as the urban region should be regarded in its totality. Therefore, I focus our attention on how urban form facilitates the accessibility of social support and economic opportunity.

Empirical work has shown that there are gender differences in commuting behaviour. Women tend to find employment close to their homes and therefore have shorter journeys to work, and rely more on public transit than driving (Hanson and Pratt, 1988; Blumen, 1994; Rosenbloom, 2004). Relative to men, women dominate lower-skilled, lower-paying jobs, that are geographically decentralized from the downtown core. With lower expected incomes than their male counterparts and the expectation to attend to domestic responsibilities, the costs of travelling longer distances to work is not worth it for many women (Johnston-Anumonwo, 1992; Blumen, 1994; Turner and Niemeier, 1997; Kwan, 1999). The spatial divide of home and work, coupled with poor transit accessibility to better economic opportunities, have contributed to creating a captive labour market of women in the suburbs (Rutherford and Wekerle, 1988). Improving transit access for women increases the probability that they will be able to gain employment (Ong and Houston, 2002).

However, the infrastructure upon which the journeys to work occur has been relatively overlooked. Transit systems can be improved and made more equitable, but is ultimately constrained by the physical space that it occupies. Hence, the deeper question behind urban mobility and access to economic opportunity should consider how the underlying spatial form facilitates or obstructs movement. There is a burgeoning empirical literature on the ways that urban form facilitates transportation and mobility, thereby shaping economic, environmental, and social outcomes in cities. Urban compactness allows for better transit accessibility and public service provision, and therefore affects where households choose to locate and the productivity level of firms. Compact and connected cities experienced greater labour productivity (Cervero, 2001) and have larger populations and lower wages (Harari, 2020). The road network plays a critical role in urban connectivity, as it is provides the

infrastructure for people and capital to flow. Within the city, a gridiron road network is associated with better urban mobility (Akbar et al., 2018). Outside of the city, highways and ring roads lead to the decentralization of industry and population (Baum-Snow, 2007; Baum-Snow et al., 2017).

Urban connectivity can be measured by the Street Network Disconnectedness Index (SNDI) (Barrington-Leigh and Millard-Ball, 2019). The SNDI is a composite of the nodal degree, dendricity (tree-likeness), circuity, and sinuosity of the street network. In comparison to measures of nodal density or conformity to a gridiron street network, such as in Akbar et al. 2018, the SNDI is applicable to contexts outside of North America, allowing for a broader conception of what a highly connected urban region looks like. It also takes into account the configuration of the street network that commuters interact with, which eludes studies of cities' geometric shapes, such as in Harari (2020). A high SNDI indicates that the street network is highly disconnected, and correlates with high automobile dependency and low rates of walking (Barrington-Leigh and Millard-Ball, 2019). Our hypothesis suggests that high connectivity, captured by a low SNDI, correlates with high female LFP.

How urban form shapes female LFP rates has been studied in recent empirical work. In studies on Oman and Japan, Mansour (2018) and Sakanishi (2020) showed that there is spatial heterogeneity in the distribution of female LFP rates within countries, with urban regions having higher levels of female economic participation. Furthermore, a higher level of compactness in neighbourhoods leads to closer gender parity in the spatial extent of activity, including work, between husbands and wives (Lo and Houston, 2018). The geographical access to childcare services from home also affects mothers' LFP (Van Ham and Mulder, 2005). Using the SNDI, this paper builds upon these findings to explore how urban connectivity affects female LFP rates.

3 Research Questions

To study gender differences in commuting behaviour, and the relationship between urban connectivity and female LFP, I use data from Barrington-Leigh and Millard-Ball (2019)'s study of global street network connectivity and the 2016 Canadian Census (Statistics Canada, 2016).

My research questions are as follows:

1. Do Canadian men and women have different patterns of commuting?

   According to existing literature, men predominantly travel by car, and women by public transit. Men also have longer commutes to work than women. I examine the differences in commuting behaviour between Canadian men and women to verify if these observations hold in the Canadian context.

2. Is commuting in Canada shaped by urban connectivity?

   In their validation of the SNDI, Barrington-Leigh and Millard-Ball (2019) showed that SNDI correlates well with measures of walkability and automobile dependence in existing literature. I examine how the level of connectedness in a census tract's street network correlates with the commuting choices of its residents.

3. How does urban connectivity affect female LFP?

   Having established that women and men commute differently, and that commuting decisions are a function of urban connectivity, we can infer the impact of connectivity on women's access to economic opportunity. I hypothesize that better urban connectivity, measured by low SNDI, is related to higher rates of female LFP.

4 Data and Methods

The first and second research question use census data on men and women's commuting behaviour to work at the census tract scale. Two aspects of commuting behaviour are considered: mode and duration. There are four modes of commuting included, namely automobile use, as a driver or as a passenger, public transit, and walking. Commuting duration is split into five levels: less than 15 minutes, 15 - 29 minutes, 30 - 44 minutes, 45 - 59 minutes, and more than 60 minutes. The distributions of commuting modes and duration can be see in Figure 1. Using data from Barrington-Leigh and Millard-Ball (2019), urban connectivity is measured by SNDI for the street network (as of 2018) within each census tract's geographical extent. A total of 5608 census tracts were included for analysis. Men and women use similar modes of transportation. For both genders, commuting by automobile, as a driver, is the most popular mode, followed by public transit. More women commute as a passenger in an automobile, than commute by walking. However, men walk more than they commute as a passenger. The distribution of commuting durations between men and women appears to be different. Most men and women spend between 15 to 29 minutes on commuting, and for women the next most common commuting time is less than 15 minutes, while for men it is 30 to 44 minutes. To identify if male and female patterns of commuting are different, paired t-tests on each variable. The proportion of commuters who drive and use public transit, the two most popular modes of transport, are calculated and Pearson's correlation coefficient is measured for the proportions and SNDI. The same method is applied to commuting duration. These measures of correlation reveal if spatial connectivity affects commuting behaviour.

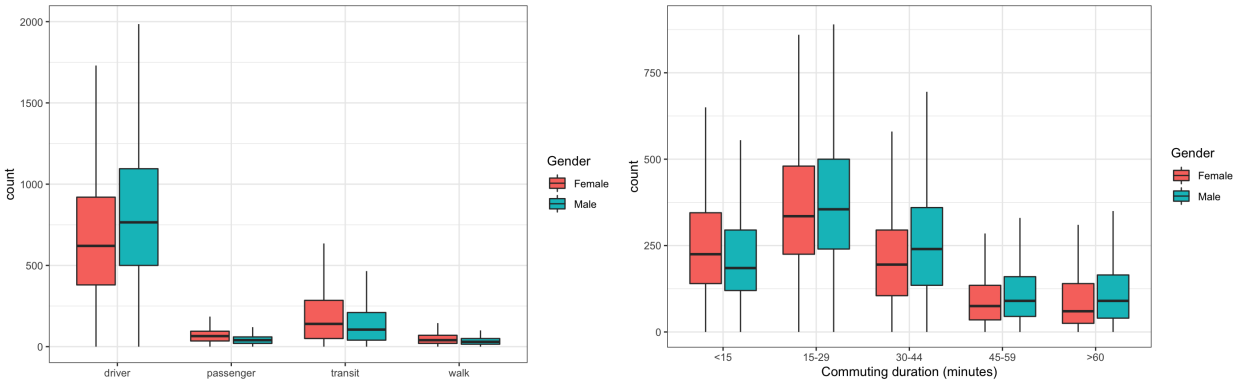

Figure 1: Commuting modes (left) and duration (right) by gender.

For the third research question, an ordinary least squares model is used to study the determinants of female LFP. The census provided data on the dependent variable, LFP

Variables	Mean	Std. Dev.	Min	Max
Female LFP	61.9	8.26	12.7	100.0
LFP gap (male LFP - female LFP)	8.267	4.27	-49.4	31.1
SNDI	2.227	1.714	-1.384	10.626
Household characteristics:				
Median household income (in thousands)	78.232	29.497	17.05	334.17
Average number of rooms	6.168	1.32	2.4	10
Households with children (%)	40.896	13.637	1.911	79.167
Commuting characteristics:				
Drivers who are female (%)	44.343	4.983	0	71.43
Public transit users who are female (%)	57.126	13.86	0	100

Table 1: Summary statistics for LFP and its determinants.

rates, and other independent variables that have been demonstrated to have an impact on female LFP. This includes household characteristics, such as household income, the size of the dwelling, and the presence of children, and commuting characteristics, namely the proportion of drivers and transit users who are female. The main independent variable is urban connectivity, measured by SNDI. After excluding missing observations, I retained a sample of 5425 census tract observations for analysis. Table 1 summarizes the variables used in this study. With an average SNDI of 2.227, census tracts across Canada have relatively well-connected street networks. The other independent variables have been included as controls. As this analysis takes place at the scale of the census tract, and not households, variables such as women's education level and age were omitted. State policies on childcare, family taxation, and labour regulations have been shown to affect female LFP (Jaumotte, 2004; Thévenon, 2013). However, policy effects were omitted from this analysis as it is assumed that there would be less variation within the country and thus have a smaller effect on the census tract scale of comparison, as compared to the country-level comparisons that they have featured in. It is possible that this assumption might overlook Quebec's uniqueness in the Canadian context, especially when it comes to childcare policies (Beaujot et al., 2013). After a steady increase beginning in the 1950s, female LFP in Canada has stagnated since the early 1990s with an average annual increase of 0.3 percentage points (Statistics Canada, 2018). The stability of female LFP rates thus makes spatial comparison possible, as this allows us to rule out macroeconomic variables acting on it. Female LFP lags behind male LFP, and male LFP rates is, on average, 8.267 percentage points higher than female LFP in a census tract. For a closer consideration on the impact of urban form on female LFP, I apply the model to two municipalities with different levels of urban connectivity: Montreal, with an average SNDI of 0.464, and Calgary, with an average SNDI of 2.526. I also evaluate the impact of urban connectivity on the male and female LFP gap.

	Female	Male	Alt. hypothesis	Mean diff.	Sig.
Commuting mode:					
Driver	697.2	847.5	$\mu_{\text{Female}} < \mu_{\text{Male}}$	-150.289	***
Passenger	72.65	44.56	$\mu_{\text{Female}} > \mu_{\text{Male}}$	28.089	***
Public Transit	195.9	146.7	$\mu_{\text{Female}} > \mu_{\text{Male}}$	49.250	***
Walk	62.77	51.58	$\mu_{\text{Female}} > \mu_{\text{Male}}$	11.190	***
Commuting duration:					
< 15 minutes	266	228.3	$\mu_{\text{Female}} > \mu_{\text{Male}}$	37.771	***
$15 - 29$ minutes	374.3	395.2	$\mu_{\text{Female}} < \mu_{\text{Male}}$	-20.897	***
$30 - 44$ minutes	219.3	267.6	$\mu_{\text{Female}} < \mu_{\text{Male}}$	-48.249	***
$45 - 59$ minutes	95.54	113.1	$\mu_{\text{Female}} < \mu_{\text{Male}}$	-17.550	***
> 60 minutes	96.58	122.3	$\mu_{\text{Female}} < \mu_{\text{Male}}$	-26.630	***

Significance: $p = 0$ '***'

Table 2: Mean gender differences in commuting modes and durations.

5 Commuting behaviour

5.1 Gender differences in commuting modes and duration

The paired t-tests for mean differences in commuting modes and durations by gender are statistically significant (Table 2). On average, men are likelier to be drivers, while women are likelier to be passengers, use public transit, and walk on the commute to work. Women also have shorter commutes than men in general, and people who commute less than 15 minutes to work are likelier to be women than men.

These results corroborate empirical observations about the journey to work in other contexts. Blumen (1994) gives several explanations for the difference in male and female commuting patterns. The status of women in the labour market, their social role of managing household social reproduction, the availability of transportation options, and the location of their home and place of employment, all contribute to the difference. This suggests that urban connectivity can affect women's mobility, which in turn influences female LFP.

5.2 Commuting and urban connectivity

I establish the relationship between commuting behaviour and urban connectivity by testing the correlation between the commuting variables and SNDI. Specifically I compare the proportion of the households within a census tract using a specific commuting mode or having a given commuting duration. Doing so allows us to think of the variables as commuting choices that households make within the urban form of their neighbourhoods.

The correlation between SNDI and all commuting modes is statistically significant. As the street network becomes more disconnected, households are likelier to drive ($R = 0.65$), and less likely to use public transit ($R = -0.54$) or walk ($R = -0.46$). The correlation of SNDI and commuting as a passenger is statistically significant but weakly positive ($R = 0.18$). Since automobile dependency increases with street network disconnectedness, this correlation might instead be capturing other household characteristics, such as income levels.

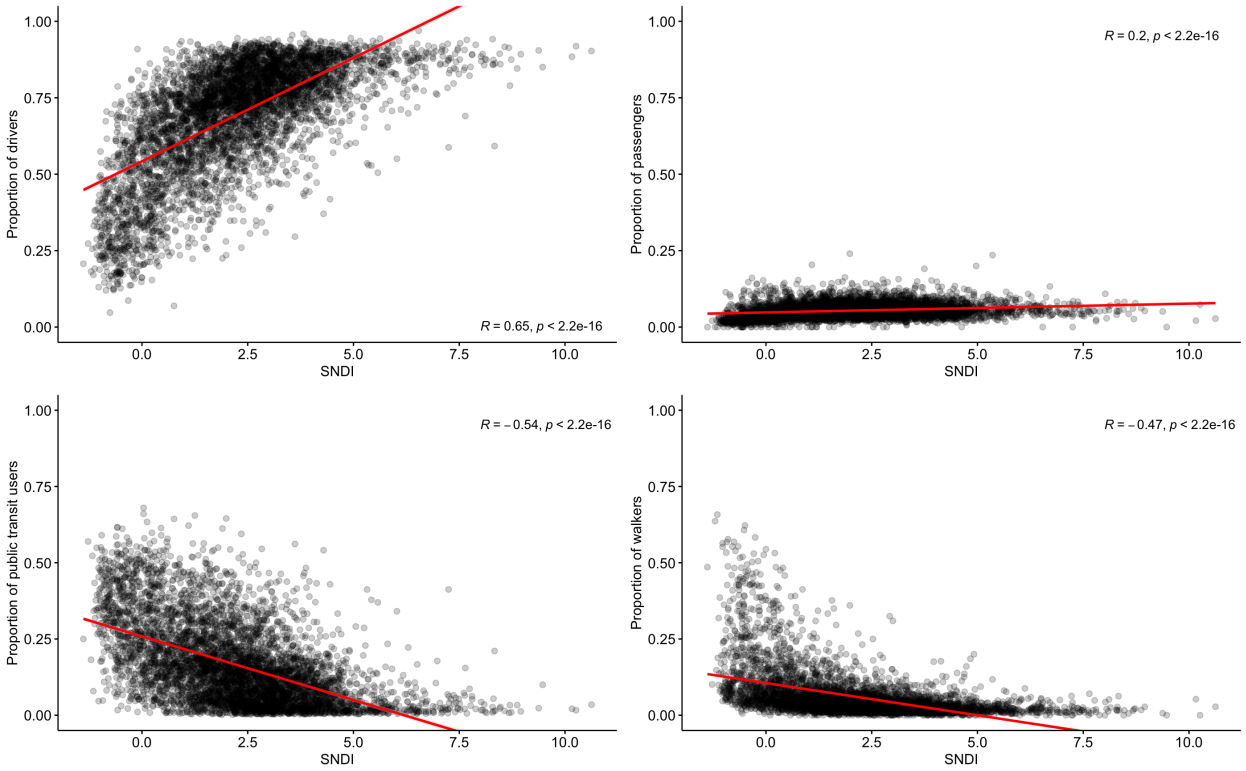

Figure 2: Correlation between SNDI and commuting modes.

For instance, commuting as a passenger might imply that the street network is unconducive towards transit and walking, but the household cannot afford more than one car to travel with.

SNDI and commuting durations are weakly correlated (results presented in Table 3). This might be because households' choices of commuting modes offset commuting durations (i.e. it is faster to drive than it is to walk), dampening the expected effect. Additionally, Blumen (1994) noted that time is not an objective measure of commute, because men and women have different notions of what commuting time comprises; instead, distance might be a better indicator.

6 LFP and street network connectivity

Our prior analysis has shown that men and women have different commuting patterns, and that the choices that households make in commuting modes is shaped by urban connectivity. The literature on female LFP identifies the journey to work as an important factor. Thus, we can infer that urban connectivity will have differential impacts on men and women, and affect female LFP rates.

An OLS model is used to determine the relative influences of urban connectivity on female LFP and the gender gap in LFP . The OLS model is a good fit for the data, with $R^2 = 0.209$ for predicting female LFP (including male LFP as an independent variable brings the R^2 to 0.772) and $R^2 = 0.145$ for predicting the LFP gap. The F-tests for both models are also

	Pearson's R	Sig.
Commuting duration:		
< 15 minutes	0.117	***
$15 - 29$ minutes	-0.001	
$30 - 44$ minutes	-0.149	***
$45 - 59$ minutes	-0.049	**
> 60 minutes	0.061	***

Significance: $p = 0$ '***', $p < 0.001$ '**'

Table 3: Correlation tests between SNDI and commuting duration.

statistically significant. We might want to account for regional effects, and so I also fit the data to a multilevel regression model with the census tract's municipality as a random effect, and find that it yields effectively the same results as the OLS model, but the OLS model has smaller residuals (although negligibly so). Thus, I proceed with using the OLS model for this study. While the residuals are more or less normally distributed, they appear to vary linearly with the predicted values. The heteroskedasticity in the model is confirmed by the Breusch-Pagan test.

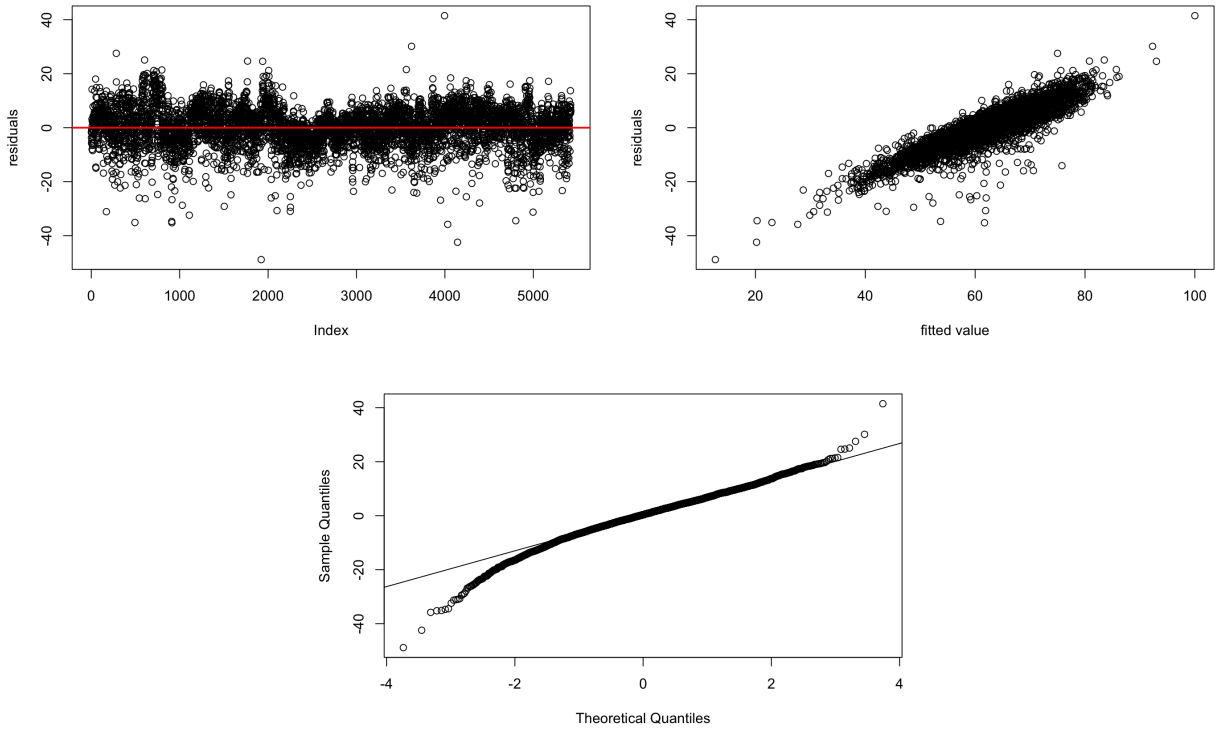

Figure 3: Residual diagnostics for OLS model: distribution of residuals (top left), residuals versus fitted values (top right), normal quantile-quantile plot (bottom).

The results of the OLS analysis are presented in Table 4. As expected, SNDI has a

statistically significant effect on female LFP, as well as the LFP gap. An increase in street network disconnectedness by 1 index point leads to a fall in female LFP by 0.493 percentage points, and drives up the gap between male and female LFP by 0.315 percentage points. While this may seem like a small value, this amount is comparable to Canada's year-on-year increase in female LFP at 0.3 percentage points. Commuting characteristics in the census tract also affect female LFP: a 1 percentage point increase in the proportion of drivers who are female leads to a 0.364 percentage point increase in female LFP, confirming that women's mobility affects their access to employment.

I also consider the effect of urban connectivity on the LFP gap, to identify if a more connected street network leads to increases in LFP in general, or if connectivity helps gender parity in the accessibility of economic opportunity. SNDI is indeed a statistically significant predictor for the LFP gap, with increasingly disconnected street networks associated with a larger gap between male and female LFP. This suggests that there is a gendered dimension of how connectivity is experienced. Previous work has shown that the location of employment affects where households choose to settle down. As men tend to have access to higher paying jobs, and given social norms where the man is viewed as the head of the household, it follows that households would prioritize locations convenient for the male commute, potentially at the expense of women. In this scenario, greater urban connectivity can help women access employment too.

	Female LFP		LFP gap	
	Est.	Sig.	Est.	Sig.
(Intercept)	46.17	***	22.043	***
SNDI	-0.493	***	0.315	***
Household characteristics:				
Median household income (in thousands)	0.177	***	0.017	***
Average number of rooms	-2.768	***	-0.283	**
Households with children (%)	0.072	***	0.024	***
Commuting characteristics:				
Drivers who are female (%)	0.364	***	-0.305	***
Public transit users who are female (%)	0.018	*	-0.027	***

Significance: $p = 0$ '***', $p < 0.001$ '**', $p < 0.01$ '*'

Table 4: OLS analysis of determinants of female LFP and LFP gap.

To take a closer look at the relationship between urban connectivity and female LFP, I consider two municipalities with varying levels of SNDI. Montreal has an average SNDI of 0.464, whereas Calgary is slightly above the Canadian average, at 2.52. Both of these municipalities, or census subdivisions, were chosen for comparison as they had similar population sizes. Figures 4 and 5 show the geographical distribution of female LFP rates and SNDI in Montreal and Calgary respectively. It is noticeable that the downtown areas have high levels of female LFP relative to the urban periphery in both municipalities, and these areas are also more connected.

The same OLS model is applied to observations from Montreal and Calgary, and the

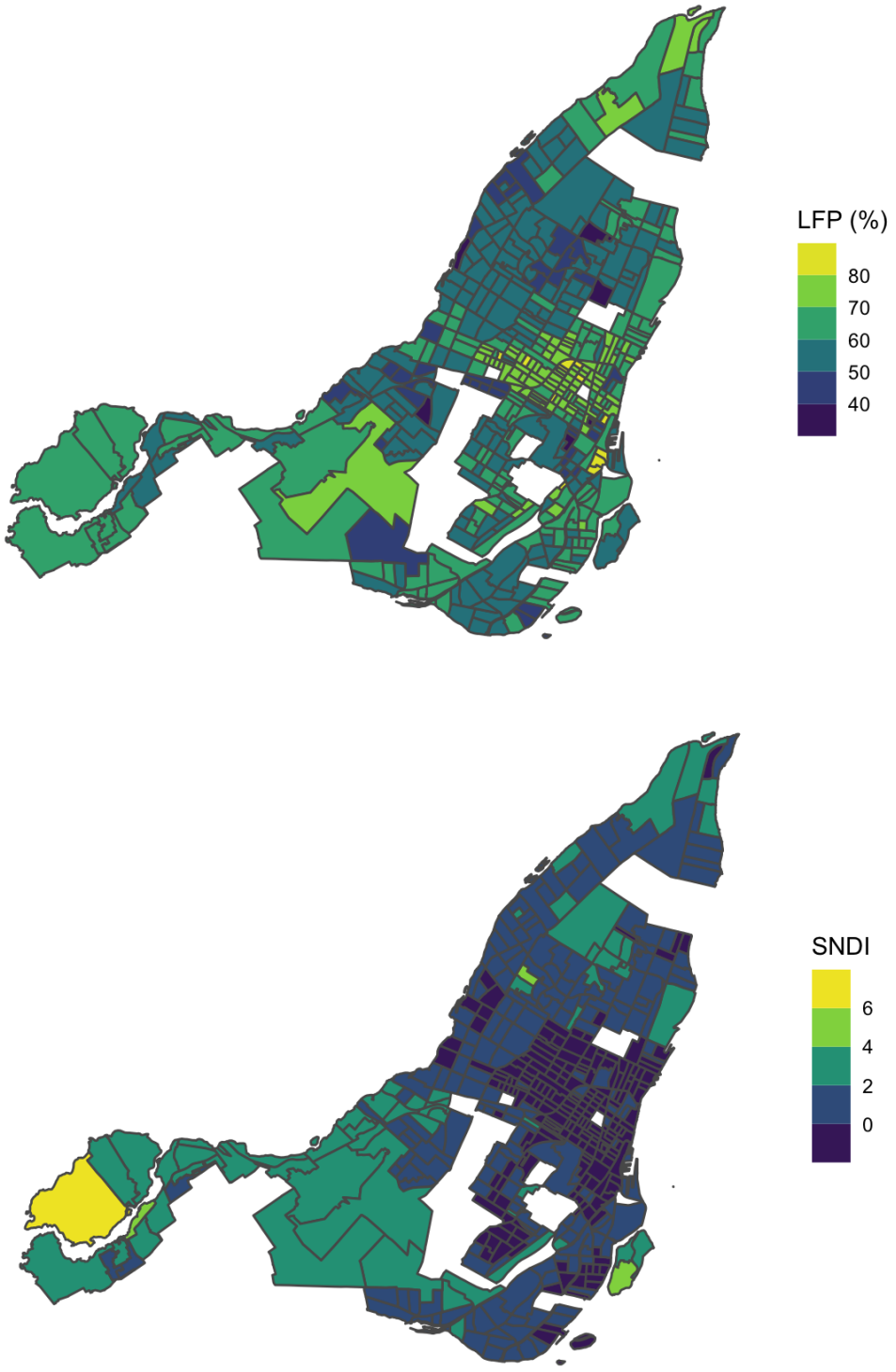

Figure 4: Census tracts in Montreal: distribution of female LFP (top) and SNDI (bottom).

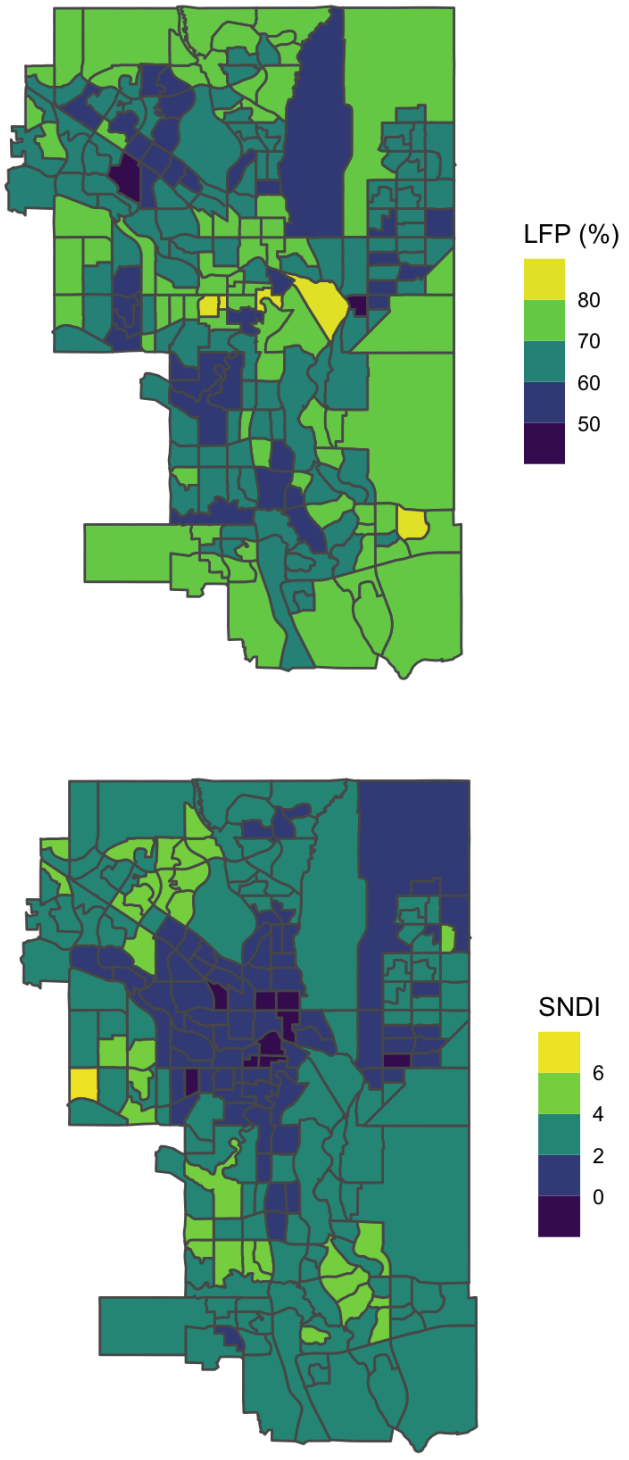

Figure 5: Census tracts in Calgary: distribution of female LFP (top) and SNDI (bottom).

results are presented in Table 5. SNDI is statistically significant in both municipalities, but its effect is more pronounced in Montreal, where an increase in SNDI by 1 point corresponds with a 2 percentage point decrease in female LFP. In Calgary, female LFP would fall by 0.8 percentage points. This is a larger effect than the national level model, suggesting that the effect of SNDI might vary with the geographical scale of analysis. This should be expected, as the mechanism by which connectivity affects female LFP is in the commuting and locational decisions of households, which takes place within certain geographical constraints. However, further investigation is needed to identify how the level of street network disconnectedness affects female LFP. As Figure 6 suggests, SNDI may correlate with female LFP, but only up to a certain point. Further investigation is needed to identify what other factors may be moderating urban connectivity.

	Montreal		Calgary	
	Est.	Sig.	Est.	Sig.
(Intercept)	45.660	***	26.877	***
SNDI	-1.993	***	-0.818	*
Household characteristics:				
Median household income (in thousands)	0.146	***	0.115	***
Average number of rooms	1.344		-5.057	***
Households with children (%)	-0.333	***	0.162	***
Commuting characteristics:				
Drivers who are female (%)	0.230	***	0.927	***
Public transit users who are female (%)	0.082		0.290	***
Adjusted R^2	0.325	-	0.483	-
F-statistic	$38.24_{\{6,459\}}$	***	$36.12_{\{6,220\}}$	***

Significance: $p = 0$ '***', $p < 0.001$ '**', $p < 0.01$ '*'

Table 5: OLS analysis of determinants of female LFP in Montreal and Calgary.

There is also evidence that the determinants of female LFP may vary within Canada too. For instance, the percentage of households in a census tract with children is a statistically significant predictor for female LFP in both municipalities, but the direction of the relationship is opposite: in Montreal, greater presence of children leads to a fall in female LFP, while in Calgary, female LFP actually increases. If it is assumed that households follow traditional gender norms, where mothers have a larger role in childcare, then we expect to see the negative relationship between greater child presence and female LFP as observed in Montreal. However, the opposite relationship in Calgary could be explained by higher expenditures incurred from having children. Just like how women entered the labour force to support increased household expenditures in an era of mass consumption, the costs of raising children may necessitate dual-income households, even if commuting to work is inconvenient. Overall, the differences in the determinants of female LFP at the municipal level suggests that there are other factors at play.

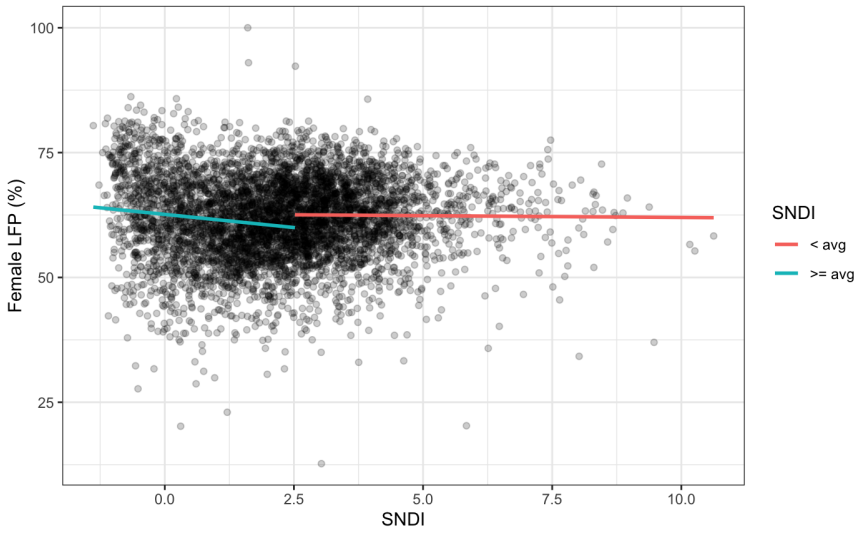

Figure 6: Female LFP against SNDI, with separate linear regression lines for observations with below and above average SNDI.

7 Conclusion

The data on Canadian men and women's commuting behaviour confirms empirical observations of the gender differences in the journey to work – automobile use skews male while transit users tend to be female, and women have shorter commutes than men. I establish further that commuting in Canada is shaped by urban connectivity at the census tract scale, especially in the mode of commute. Building upon these two observations, I evaluate the feminist critique that urban form disadvantages women's economic participation because of spatial alienation, by studying the effect of urban connectivity on female LFP rates. I find that there is indeed a statistical relationship, where higher levels of urban connectivity are associated with higher rates of female LFP. However, this relationship is not a straightforward one, and requires closer research.

The confirmation of the hypothesis that female LFP is affected by the connectivity of the street network opens up new possibilities for research on how spatial form could be a point of intervention in promoting social equity. As Lo and Houston (2018) note in their study of neighbourhood compactness and gender equality in activity space, policies promoting compact development primarily focus on its environmental sustainability, but it is exciting that compactness may also have positive outcomes for gender equality. This work also extends on earlier feminist critiques of urban planning, which focused on the dichotomy between urban and suburban, home and work. With new patterns of development and population growth creating "in-between cities" (Young and Keil, 2010), the divide between urban and suburban has become obsolete, necessitating new modes of conceptualizing urban form. Connectivity can be one such way; in this study, I show that connectivity, a defining characteristic between the urban and suburban, can offer some explanation for women's economic participation as theorized previously. Another aspect of previous work on the gender division of space that may benefit from a more modern review is the assumptions of heteronormativity and the gender binary. As Doan (2010) reveals, there is a continuum between public and private

spaces, and people who fall outside of the binary of male and female have a vastly different experience in navigating these gendered spaces. Further research could consider how connectivity affects economic outcomes for households comprising individuals who are not heterosexual or cis-gendered.

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