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Intra-metropolitan spatial patterns of female labor force participation and commute times in Tokyo

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A B S T R A C T

We explore *intra*-metropolitan spatial patterns of female labor force participation, and examine how they relate to commute times in Tokyo. The spatial patterns differ markedly by marital status and the presence of children. For married mothers, the spatial clusters of low participation and regular employment rates are largely located in the inner suburbs, many of which overlap with the spatial clusters of long male commute times. The spatial regression results indicate that for married mothers, a longer commute time is significantly associated with lower participation and regular employment rates, while for unmarried and childless married women, these associations are mostly nonsignificant. Among married mothers, the magnitude of the negative associations is greater for college graduates than for those with a high school education or less, suggesting that highly educated mothers are especially sensitive to commute times. We argue that the spatial transportation constraint intensifies the household division of labor, resulting in unique patterns for married mothers.

1. Introduction

Geographic disparities in female participation in the labor market have drawn increased attention in urban and labor economics. Recent studies show that female participation varies considerably across regions, such as metropolitan areas, counties, and prefectures (Abe, 2011; Fogli and Veldkamp, 2011; Black et al., 2014); the regional variations in female participation are much greater than those in male participation (Abe, 2013). Some have argued that commute time is an important factor of the large regional variations in female participation (Abe, 2011; Black et al., 2014). Using inter-metropolitan data on commute times in the US, Black et al. (2014) find negative associations between commute times and labor force participation of married women. However, empirical evidence of the role of commute times in female participation is limited. In particular, the *intra*-metropolitan geographic disparities in female participation and their associations with commute times have not been explored using data of small geographical units.

In this study, we aim to shed new light on geographical disparities in female participation by examining *intra*-metropolitan spatial patterns of female participation and studying how they relate to commute times. Specifically, we ask the following three questions: (1) Are there specific intra-metropolitan spatial patterns of female participation? (2) Are the spatial patterns of female participation related to commute times? (3) Do the spatial patterns of female participation and their associations with commute times differ by marital status and the presence of children? We examine these questions for women aged 25–54 in Tokyo, the world's most populous metropolitan area with long commute times.

We pay particular attention to the importance of commuting for women, since female commutes are shorter than male commutes (this point is reviewed in the next section). The shorter female commutes suggest that making long commutes is not feasible for many women, because they either face greater spatial constraints or have stronger preferences for short commutes. In a large metropolitan area like Tokyo, commute times differ considerably by residential location. In the suburbs, many people spend a long time commuting to work in the central business district (CBD) via heavily congested public transportation. It is conceivable that such long commutes impede women, especially women with children, from participating in the labor market.

Our contribution to the literature is three-fold. First, we examine intra-metropolitan spatial patterns of female participation by identifying spatial clusters of high and low participation rates. The levels of female participation are unlikely to be evenly distributed within a metropolitan area; they may have distinct spatial patterns vis-à-vis urban spatial structure. For example, there may be disproportionately more married women with children who need more housing space living in the suburbs, where housing costs are modest. Such suburban

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mothers are more likely to be housewives or to be working locally rather than working full time and commuting to the CBD. By contrast, households in which both spouses work in the CBD have greater incentives to live nearby. In order to examine the spatial patterns, we employ geographic information systems (GIS) and spatial statistics—Global Moran's I and Getis-Ord G_i^*.

Second, we use municipal-level data, which are more spatially disaggregated than the inter-metropolitan data used in previous research (Black et al., 2014). The use of a smaller geographical unit (in this study, the municipality) enables us to examine intra-metropolitan geographic disparities in female participation and commute times as well as their spatial patterns. Moreover, analyzing municipal data within a metropolitan area allows us to study the role of commute times in an environment where relocation (i.e., sorting by choosing residential location) is more realistic. For example, it is unlikely that people would migrate from New York City to Minneapolis, where commuting costs are lower; however, it is likely that people would choose from locations within the Tokyo metropolitan area (e.g., Kamakura[1] versus central Tokyo) when considering commuting distance and the housing costs in each place.

Finally, we examine three groups of women aged 25–54 (unmarried, married without children, and married with children), and three rates for female participation (labor force participation, regular employment, and part-time employment).[2] A comparison of multiple demographic groups of women and these three types of participation is rare in the literature.

We find considerable intra-metropolitan disparities in female participation. The spatial patterns of labor force participation and regular employment rates differ markedly by marital status and the presence of children. Married mothers have unique spatial patterns of participation and regular employment rates. These rates are negatively and significantly associated with male commute times, while the associations are mostly nonsignificant for unmarried and childless married women. Among married mothers, the magnitude of the negative associations is greater for college graduates than for those with a high school education or less, suggesting that highly educated mothers are especially sensitive to commute times.

The next section reviews the related literature. Section 3 explains the methods, study area, and data. Section 4 presents the findings, and Section 5 concludes.

2. Related literature

2.1. Female commuting

Female commuting is shorter than male commuting. Studies consistently find this gender difference across regions and countries (e.g., Madden, 1981; Gordon et al., 1989; Hjorthol, 2000; Lee and McDonald, 2003; Crane, 2007; Roberts et al., 2011; Neto et al., 2015). The gender commute gap is large for parents: fathers have long commutes, whereas mothers have short ones (Madden, 1981; McLafferty and Preston, 1997; Hjorthol, 2000).

Researchers examine various reasons why women work closer to home. The primary explanation is the household responsibility hypothesis (HRH) based on the household division of labor in which women shoulder more housework and childcare than men (e.g., Madden, 1981; Johnston-Anumonwo, 1992; McLafferty and Preston, 1997; Turner and Niemeier, 1997). Empirical evidence on the HRH is mixed; some results support it (Turner and Niemeier, 1997; Neto et al., 2015), while others show little or blended levels of support (Gordon et al., 1989; Singell and Lillydahl, 1986). Turner and Neimeier (1997) critically review the HRH.

[1] Kamakura is a popular suburban city in Kanagawa Prefecture.

[2] In this paper, female participation includes both regular and part-time employment.

A similar but more specific explanation for women's shorter commutes is based on family support trips, such as shopping and transporting children to and from childcare centers or schools. Women make more family support trips than men, and are more likely to combine non-work trips with work trips (Hanson and Hanson, 1981; Hanson and Johnston, 1985; McGuckin and Murakami, 1999; Hjorthol, 2000). The gender difference in trip-chaining behavior is particularly noticeable when children are present. McGuckin and Murakami (1999) find that women with young children are far more likely than men (and women without children) to make multiple stops linked to their commutes. Boarnet and Hsu (2015) discover that within households with children, women make considerably more chauffeuring trips than men, while the non-work trips of men and women do not differ much when they do not have children. These findings suggest that mothers are more sensitive to commute times than men or women without children.

Evidence also suggests that long commutes are especially burdensome for women with young children (Rouwendal, 1999). When traveling with infants and toddlers, mobility becomes limited, and spatial constraints increase in severity. Commuting may involve unexpected trips to and from the hospital when a child falls ill. Roberts et al. (2011) demonstrate that commute time adversely influences the psychological health of women, especially those with preschool-aged children. They find no such negative effects for single men and women without children, those working with flexible schedules, or those who rely on their partners for childcare. Their findings imply that women who do more child-rearing and housework face greater psychological barriers for long commutes than those who have less housework. These psychological barriers may prevent women from working jobs that require long commutes.[3]

2.2. Commuting time, female labor force participation, and urban spatial structure

Basic urban models indicate that housing and commuting costs are closely related to urban spatial structure. In the monocentric city model formulated by Alonso (1964), Muth (1969), and Mills (1972), there is a tradeoff between housing and commuting costs. The farther the distance from the CBD, the lower the housing prices, and the higher the commuting costs. This pattern is found in metropolitan areas around the world, although actual patterns are more complex.

The monocentric city model has three implications for spatial patterns of labor supply by married women. First, to secure enough residential space, families may decide to live farther away from the CBD. Consistent with this hypothesis, Madden (1981) finds that compared to unmarried women, married women live in larger homes and farther from the city center. Suburban living makes it costly for both spouses commute to the CBD, especially in large metropolitan areas. Of people who commute to the Tokyo ward area (referred to as the CBD in this study), half spend 60 minutes or longer, and 15% spend 90 minutes or longer for a one-way commute (TMRTPC, 2010). The likely allocation between spouses is that the one with the comparative advantage for market work (i.e., the husband) would commute to the CBD, while the other (i.e., the wife) would either stay home or work locally. When this division within household occurs, the husband spends a long time commuting, while the labor market participation of the wife is low. McLafferty and Preston (1997) find that married

[3] The hypotheses are based on the household division of labor (i.e., labor supply factors). Other explanations for women's shorter commutes come from labor demand. For example, women tend to have lower wages, higher job turnover rates, and shorter work hours, which reduce economic incentives for making long commutes (Madden, 1981; White, 1986; MacDonald, 1999). In another instance, differences in the spatial distributions of jobs suitable for women and men could explain gender disparities in commuting: female jobs are more dispersed, whereas male jobs are more concentrated (Hanson and Johnston, 1985; MacDonald, 1999).

men, more than unmarried men, spend longer times commuting, and argue that the unequal division of labor in which women do more housework frees up time for men to spend on long commutes.

Second, for households with children, the need for space and parents' time value at home are both high. Households with children may also value residential amenities that benefit their children, such as schools and neighborhoods (Gamsu, 2016; Brasington, 2017). In the suburbs, a division of the market and household work between parents—the father commutes to the CBD and the mother stays home or works locally—is more likely to take place.

Finally, dual-earner households in which both spouses work in the CBD are willing to pay both spouses' sum of time cost to pay for locations close to the CBD; therefore, such households are likely to live near the CBD and have shorter commutes (Abe 2011). Hjorthol (2000) reports that in Oslo, the commuting distance of married women and men is the shortest in the central parts of the metropolitan area.

These implications from the monocentric city model suggest that costly commuting and lower housing prices in the suburbs induce a sharp division of labor between husbands and wives in the suburbs, especially for couples with children.

3. Methods

3.1. Spatial patterns of female participation

We examine the spatial patterns of female participation by calculating the Global Moran's I and Getis-Ord G_i^* statistics. Global Moran's I (Moran, 1950) is a global measure of spatial autocorrelation.[4] In this study, we use Global Moran's I to evaluate whether the spatial patterns are random, clustered, or dispersed. The Moran's I value (I) is calculated as:

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}(x_i - \overline{X})(x_j - \overline{X})}{\sum_{i=1}^{n}(x_i - \overline{X})^2} \tag{1}$$

where n is the number of spatial units indexed by i and j, x denotes the variable of interest, $\overline{X}$ is the mean of x, and $w_{i,j}$ indicates the spatial weight between i and j. The null hypothesis is that the values being analyzed are randomly distributed across space (or no spatial autocorrelation). If the Moran's I statistic is significant, a positive Moran's I value denotes spatial clustering, whereas a negative Moran's I value indicates spatial dispersion. Note that the Moran's I value is a global measure; it is a single measure for an entire study area (in this study, the Tokyo metropolitan area) and does not illustrate the locations of spatial clustering within the study area.

On the other hand, the Getis-Ord G_i^* statistic (Getis and Ord, 1992; Ord and Getis, 1995) is a local measure of spatial autocorrelation, which is calculated for each spatial unit (the municipality in this study) within the study area.[5] Therefore, the G_i^* statistics identify the locations of spatial clusters of high values (hot spots) and low values (cold spots) if such spatial clusters exist. The G_i^* statistic is calculated as:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \overline{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \tag{2}$$

where

$$\overline{X} = \frac{\sum_{j=1}^{n} x_j}{n} \tag{3}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\overline{X})^2} \tag{4}$$

n is the number of spatial units indexed by i and j, x_j is the value for j, and $w_{i,j}$ is the spatial weight between i and j. The G_i^* statistic is essentially a z-score. A positive and significant G_i^* statistic indicates a spatial clustering of high values, wherein a larger statistic indicates a more intense clustering of high values. A negative and significant G_i^* statistic denotes a spatial clustering of low values, wherein a smaller statistic denotes a more intense clustering of low values. Using GIS, we plot the G_i^* statistics on maps to examine the spatial patterns of hot and cold spots.

For the spatial weight for the Moran's I and G_i^* statistics, we use the first-order binary contiguity matrix based on the rook criterion, in which two spatial units are defined as neighbors when they share a common border. The contiguity matrix is commonly used as the spatial weight matrix for data represented by areal units (polygons) that vary in size. We also experiment with other spatial weights to check whether the results are sensitive to the choice of weights. In calculating Moran's I, the row elements of the spatial weight matrix are standardized so that their sum equals one. For the G_i^* statistics, the row standardization is irrelevant; the statistics are invariant to the standardization.

In the spatial weight matrix, the number of neighbors for each municipality is small, ranging from 1 to 11 (mean: 5.28; standard deviation: 1.88) for the 243 municipalities in our study area (explained in Section 3.3). Therefore, for the local measure (Getis-Ord G_i^*), we calculate the pseudo p-values based on permutation (number of permutations: 99,999) and determine the significance based on the pseudo p-values. With 99,999 permutations, the numbers of hot and cold spots at the 1% significance level are robust to the particular random permutation.

3.2. Spatial regression

Next, we use regression analysis to examine the relationships between commute times and the three participation measures (female labor force participation, regular employment, and part-time employment rates). For the regression analysis, we employ the spatial Durbin model (SDM), which includes spatial lags of the dependent variable as well as the explanatory variables (Anselin, 1988; LeSage and Pace, 2009). Female participation at a specific location may depend on female participation at neighboring locations, and vice versa. Fogli and Veldkamp (2011) show that women learn participation in the labor market from nearby employed women. Female participation at a particular location may also depend on commute time and other characteristics at neighboring locations, and vice versa. Vega and Elhorst (2017) demonstrate that characteristics in neighboring regions play a significant role in female participation. LeSage (2014) suggests the use of the SDM when endogenous interactions and feedback effects, or global spatial spillovers, are present. We also estimate the standard model with ordinary least squares (OLS), a non-spatial specification, for comparison.

The SDM model and its data generating process are shown in Eq. (5) and Eq. (6), respectively (LeSage and Pace, 2009; Elhorst, 2014).

$$y = \rho Wy + \alpha\iota_n + X\beta + WX\theta + \varepsilon \tag{5}$$

$$y = (I_n - \rho W)^{-1}(\alpha\iota_n + X\beta + WX\theta + \varepsilon)$$
$$\varepsilon \sim N(0, \sigma^2 I_n) \tag{6}$$

In Eq. (5), y is an n × 1 vector of observations on the dependent variable, W represents the n × n spatial weight matrix, ρ is the spatial

[4] As a global measure of spatial autocorrelation, we employed Global Moran's I rather than Getis-Ord General G (Getis and Ord, 1992) since our data exhibit clustering of both high and low values. When both high and low values cluster, the General G is less appropriate, since the high and low values are likely to cancel each other out.

[5] As a local measure of spatial autocorrelation, we employed Getis-Ord G_i^* rather than local Moran's I (Anselin, 1995) since we are interested in the spatial patterns of the clustering of high and low values. In local Moran's I, a positive value represents a clustering of high or low values. A negative value indicates a spatial outlier. Since detecting spatial outliers is not the focus of this analysis, we use the G_i^*. Also, the G_i^* statistic, which represents a z-score, is straightforward to interpret.

autoregressive coefficient, X denotes an n × k vector of observations on explanatory variables, β and θ are k × 1 vectors of parameters to be estimated, $\boldsymbol{\varepsilon}$ is an n × 1 vector of disturbance terms, 0 represents an n × 1 vector of zeros, and $\alpha\iota_n$ indicates an n × 1 vector of ones associated with the constant term parameter α.

When ρ is nonsignificant, we proceed to estimate the spatial lag of X (SLX) model, which includes the spatial lags of the explanatory variables (WX) but does not have the spatial lag of the dependent variable (Wy). The SLX model is specified as follows (LeSage and Pace, 2009; Elhorst, 2014):

$$y = \alpha\iota_n + X\beta + WX\theta + \varepsilon \tag{7}$$

The SDM and SLX models are estimated with the maximum-likelihood (ML) method. As in the previous section, we use the row-standardized first-order binary contiguity matrix as the spatial weight matrix, W.

In the standard model estimated with OLS, the marginal effect of an explanatory variable equals the coefficient estimate of that variable. For the SDM model, on the other hand, the marginal effect does not equal the coefficient estimate because of the feedback effects (spillovers) induced by the data generating process. Therefore, we calculate the total effect, the sum of the direct effect and indirect effect, as the marginal effect. The direct and indirect effects for the rth explanatory variable in the matrix X are expressed as follows (LeSage and Pace, 2009, LeSage, 2014):

$$\partial y/\partial X'_r = (I_n - \rho W)^{-1}(I_n\beta^r + W\theta^r) \tag{8}$$

$$(I_n - \rho W)^{-1} = I_n + \rho W + \rho^2 W^2 \ldots \tag{9}$$

A change in each explanatory variable is associated with an n × n matrix of partial derivatives. The direct effect is a scalar summary measure of the own-partial derivatives ($\partial y_i/\partial X_i^r$) provided by an average of the main diagonal elements of the matrix. The indirect effect is a scalar summary measure of the cross-partial derivatives ($\partial y_j/\partial X_i^r$) (spillovers) given by an average of the off-diagonal elements, where $i \neq j$. For the SLX model, the direct effect equals the coefficient estimate (β), while the indirect effect corresponds to the coefficient estimate of the spatial lag of the explanatory variable (θ), since W is row-standardized and its main diagonal elements are zero (Elhorst, 2014; LeSage, 2014).

3.3. The study area and data

The study area is the Tokyo metropolitan area (also referred to as Tokyo in this study), comprised of Tokyo Metropolis (the metropolitan prefecture) and its three neighboring prefectures: Chiba, Kanagawa, and Saitama, excluding remote islands. Tokyo is an ideal case for this study, since it is a large metropolitan area with long commute times. In fact, population wise, Tokyo is the largest metropolitan area in the world, with 35.6 million people recorded in the 2010 Population Census. Furthermore, Tokyo's urban spatial structure resembles a monocentric city, although several sub-centers exist. The core of the metropolitan area is the Tokyo ward area (the 23-special ward area), with a densely concentrated population and business districts. In this study, the Tokyo ward area is regarded as the CBD.

The spatial unit of analysis is the municipality (*shi* = city; *ku* = ward; *machi* = town; and *mura* = village) in the 2010 census, which is the smallest level of spatial unit available for the census data used in this study. In 2010, the Tokyo metropolitan area contained 243 municipalities. We restrict the sample to municipalities with a population of 50 people or more to minimize sampling errors in participation statistics. Consequently, the number of observations (municipalities) is 243 or less, depending on the sample.

In this study, *commute time* is the average one-way travel time to work by municipality of residence (in minutes). We derive data on commute times for men and women aged 25–54 from the special tabulations of the 2008 Tokyo Metropolitan Region Person Trip Survey, obtained from the Tokyo Metropolitan Region Transportation Planning Commission (TMRTPC). The survey is conducted every ten years, and 2008 is closest to 2010. In examining relationships between commute times and the three participation measures, we use male commute times. Since most men work, employing male commute times is likely to alleviate selection bias arising from the use of female commute times.[6]

Data on labor force participation, regular, and part-time employment rates for women aged 25–54 by marital status, the presence of children, and education are from publicly available and order-made tabulations of the 2010 Population Census. The National Statistics Center of Japan provided the order-made tabulations. The *regular employment rate* is the proportion of those who work as regular employees among the population, and the *part-time employment rate* is the similar rate of part-time employees. The rates are in percentages.

In the regression analysis, the dependent variable is the labor force participation rate, the regular employment rate, or the part-time employment rate. The independent variables are commute time (the variable of interest) and control variables. Commute time is the average one-way commute time for men (in minutes), as explained above. The men and women in our data are 25–54 years old, unless otherwise noted.

The control variables include local housing prices, local income, and local unemployment rates for men, which Black et al. (2014) suggest as possible explanations for the large spatial variations in the labor force participation of married women. In addition, we use two more variables: the proportion of households with two or more children, and the availability of childcare centers. This last variable is important for this study since childcare access is found to be significantly associated with female participation in Tokyo (Kawabata, 2014). In Japan, eliminating long waiting lists for childcare centers has been an urgent policy issue. Since most childcare centers are publicly subsidized, availability is more likely to be an issue than cost, as in the cases of Italy and Germany (Del Boca and Vuri, 2007; Kreyenfeld and Hank, 2000).

Local housing prices come from the average residential land price in the 2010 Nikkei Electronic Economic Databank System (NEEDS). In the regression models, the log of the average residential land price is used.[7] The local unemployment rates for men are from the 2010 Population Census. The proportion of households with two or more children represents the fraction of households with two or more children among all households (in percentage), from the 2010 Population Census. The availability of childcare centers is represented by the ratio (in percentage) of the capacity of licensed childcare centers to the population of preschool-aged children (under 6 years old) in 2010. The data on childcare centers come from prefectural governments and municipalities, and the data on the preschool-age population are from the 2010 Population Census.

4. Empirical results

4.1. Spatial disparities in commute times and female participation

Table 1 presents the summary statistics of commute times and the three participation measures. Women have shorter commute times than men. The median one-way commute time is 38.8 min for women

[6] To mitigate selection bias, Black et al. (2014) use commute times for white married men. Commuting time data by marital status are not available in Japan.

[7] As a measure of local income, we used average annual income per person, which is calculated as total taxable annual income divided by number of taxpayers. The data are from the 2010 municipality taxation status and others [Shichoson Kazei Joukyoutou no Shirabe], available from the Ministry of Internal Affairs and Communications of Japan. However, we do not include this income variable in regressions since it is highly correlated with the average residential land price (with a correlation coefficient of 0.89).

Table 1
Summary statistics.

	Median	Mean	Std. Dev.	Min.	Max.
Commute time (min)					
Men	49.9	47.7	10.4	21.4	67.6
Women	38.8	37.0	9.2	11.7	59.7
Labor force participartion rate (%)					
Unmarried women	84.0	82.9	5.2	61.7	94.0
Married women					
No children	64.8	65.5	5.2	56.1	85.7
With children	55.1	57.4	8.7	40.5	79.6
Regular employment rate (%)					
Unmarried women	45.8	45.5	5.0	32.5	66.7
Married women					
No children	26.0	26.2	4.4	14.3	40.0
With children	14.9	16.2	4.5	10.4	37.9
Part-time employment rate (%)					
Unmarried women	17.3	17.3	4.2	6.0	32.1
Married women					
No children	23.9	24.3	6.3	8.5	46.2
With children	31.6	31.0	6.6	9.2	47.5

Note: The men and women in the samples are 25–54 years old. *Commute time* is the average one-way travel time to work. The number of observations (municipalities) is 243, except for married women without children, in which case that figure is 242.

Table 2
Global Moran's I.

	Moran's I	z-score	p-value
Labor force participartion rates			
Unmarried women	0.48	11.77	0.00
Married women			
No children	0.33	8.13	0.00
With children	0.76	18.77	0.00
Regular employment rates			
Unmarried women	0.31	7.72	0.00
Married women			
No children	0.15	3.82	0.00
With children	0.70	17.46	0.00
Part-time employment rates			
Unmarried women	0.49	12.01	0.00
Married women			
No children	0.56	13.76	0.00
With children	0.76	18.81	0.00

Note: The women in the samples are 25–54 years old. The number of observations (municipalities) is 243, except for married women without children, in which case that figure is 242.

and 49.9 min for men. The three participation measures for women differ by marital status and the presence of children. Among the three groups of women, the labor force participation and regular employment rates are highest for unmarried women (followed by married women without children), and lowest for married women with children. The median labor force participation rate is 84.0% for unmarried women, 64.8% for married women without children, and 55.1% for married women with children. The median regular employment rate is 45.8% for unmarried women, 26.0% for childless married women, and 14.9% for married mothers. In contrast, the median part-time employment rate is the lowest at 17.3% for unmarried women, 23.9% for childless married women, and highest at 31.6% for married mothers.

Table 2 reports the Global Moran's I statistics for the three participation measures. The Moran's I values are all highly significant, suggesting that the female labor force participation, regular employment, and part-time employment rates are not evenly distributed across municipalities within the metropolitan area. The positive Moran's I values imply that high and low values of these rates are spatially clustered. The intensity of the spatial clustering is greater for married women with children than for unmarried women and married women without children. In addition to the first-order contiguity, we experimented with the following spatial weights: (a) inverse distance; (b) inverse distance squared; and (c) fixed distance band (determined to include at least one municipality as a neighbor). The above results did not change when we used different spatial weights.

Fig. 1 depicts the spatial patterns of (a) male commute times and (b) their hot spots (spatial clusters of high values) and cold spots (spatial clusters of low values) based on the Getis-Ord G_i^* statistics. Male commute times exhibit considerable intra-metropolitan disparities and distinct spatial patterns. Most hot spots are located around the inner suburbs (within approximately 30km of the Tokyo ward area), suggesting that many men residing in the inner suburbs travel to the CBD, enduring long commute times. Cold spots of male commute times are located around the core parts of the CBD and in the outer suburbs around the peripheries of the metropolitan area, indicating that men residing in the outer suburbs work in the suburbs rather than commute to the CBD. The spatial pattern of female commute times (not shown) is similar to that for men but is less conspicuous; for women, there exist a lesser number of hot and cold spots.

Fig. 2 portrays the hot and cold spots of female labor force participation and regular employment rates. The spatial patterns of these rates differ notably by marital status and the presence of children. In particular, striking differences exist between married women with and without children. For married women with children, the rates of labor force participation and regular employment show more distinctive spatial patterns. Many cold spots of these rates are located around the inner suburbs, while most hot spots are located around the outer suburbs. On the other hand, for married women without children, these rates are more evenly distributed across municipalities, in

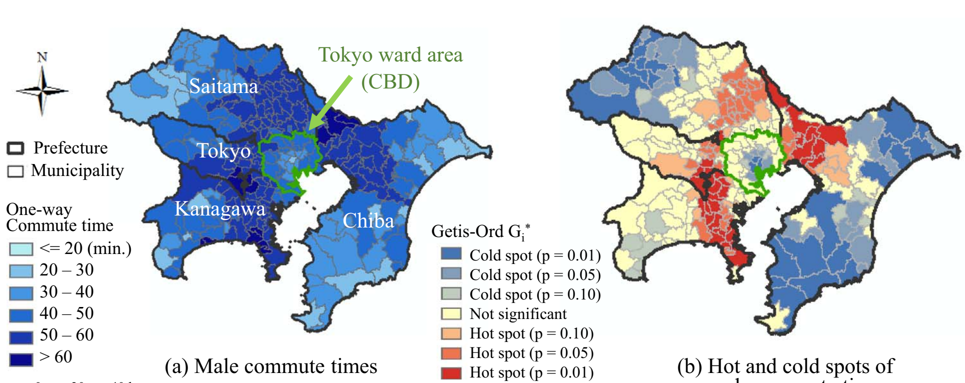

Fig. 1. Male commute times.
Note: The men are 25-54 years old.

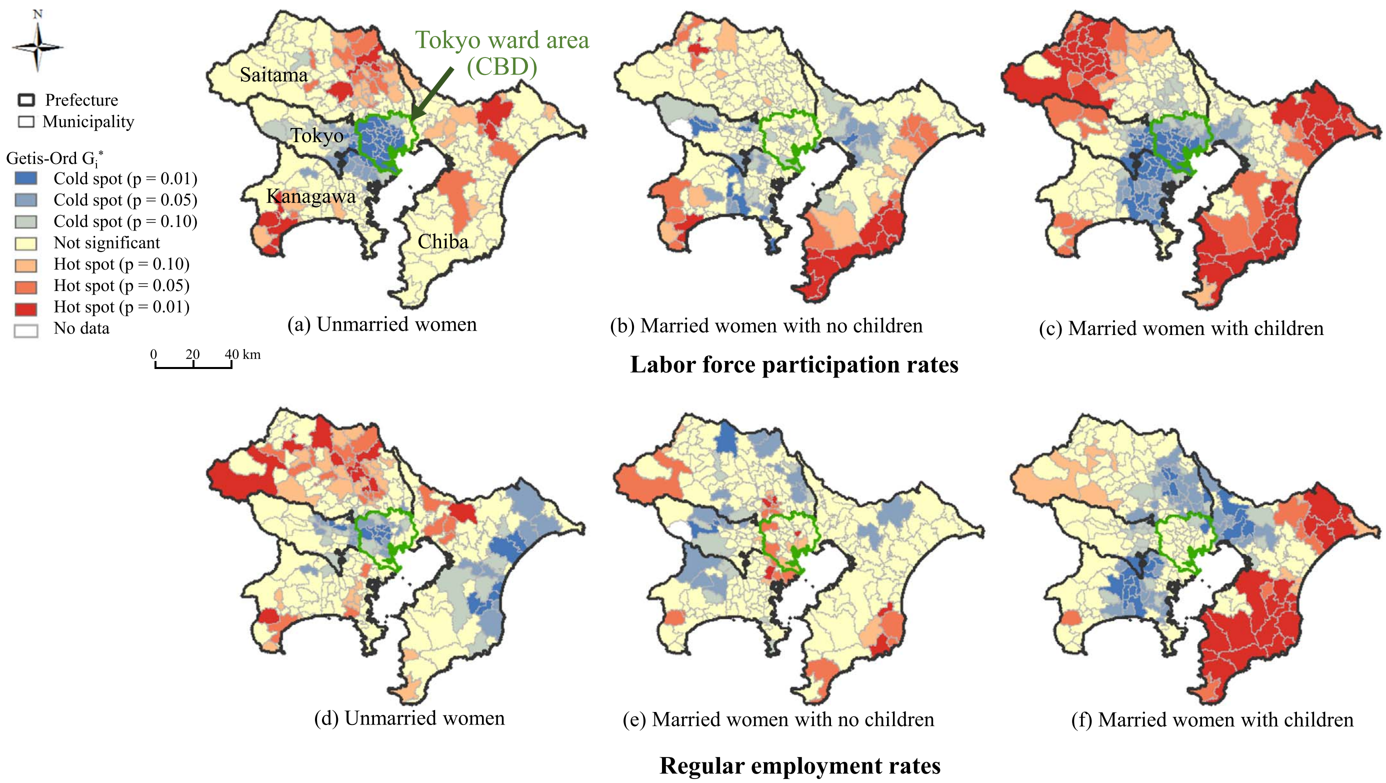

Fig. 2. Hot and cold spots of female labor force participation and regular employment rates.
Note: The women are 25-54 years old.

Table 3
Getis-Ord Gi*: correlations with male commute times.

Labor force participartion rates	
Unmarried women	0.02
Married women	
No children	− 0.59
With children	− 0.71
Regular employment rates	
Unmarried women	0.22
Married women	
No children	− 0.20
With children	− 0.78
Part-time employment rates	
Unmarried women	− 0.26
Married women	
No children	− 0.27
With children	− 0.25

Note: The men and women in the samples are 25–54 years old. The number of observations (municipalities) is 243, except for married women without children, in which case that figure is 242.

accordance with their smaller and less significant Moran's I values (see Table 2). Compared with the spatial pattern of male commute times (Fig. 1), for married women with children, many of the cold spots of the labor force participation and regular employment rates overlap with the hot spots of male commute times and vice versa (i.e., many of the hot spots of the labor force participation and regular employment rates overlap with the cold spots of male commute times). The spatial patterns of the part-time employment rates are not presented; they do not differ much by marital status and the presence of children, and have no obvious spatial relationships with male commute times.

The correlation coefficients in Table 3 support the visual relationships from the maps (Figs. 1 and 2). For married women with children, the G_i^* values of the labor force participation and regular-employment rates are highly and negatively correlated with the G_i^* values of male commute times (with correlation coefficients of −0.71 and −0.78, respectively). For married women without children, the correlations are also negative but smaller. For unmarried women, the correlations are small and positive. For the part-time employment rates, the correlations do not differ much by marital status and the presence of children.

4.2. Regression results

Table 4 reports the estimation results of the standard models and the SDM or SLX models for labor force participation rates. For comparison, we present the results for married men.

One of the statistical tests to select a model that better describes the data is the likelihood ratio (LR) test (Elhorst, 2014). The value of the LR test ($-\ 2*(\log L_{restricted}\text{-}\log L_{unrestrected})$) follows a chi-squared distribution with degrees of freedom (df) equal to the number of restrictions. For each sample, the LR test of the SDM versus standard model specifications takes a value greater than 12.6 (the 5% critical value with 6 df), suggesting the SDM as a preferred specification. Since the estimates for the spatial autoregressive coefficients (ρ) for college-educated married women without children and married women with children are nonsignificant, for those groups of women we also estimated the SLX models. The values of the LR test of the SLX models versus the standard models are all greater than 11.1 (the 5% critical value with 5 df). The LR test statistics further suggest that the SLX is a preferred specification to the SDM.[8] For these groups of women, therefore, we report the estimation results of the SLX models instead of those of the SDM models.

Table 5 presents the total, direct, and indirect effects of commute

[8] The p-values of the LR test of the SLX models versus the standard models are smaller than the p-values of the LR test of the SDM models versus the standard models.

Table 4
Regression of labor force participation.

	Married men		Unmarried women		Married women											
					No children				With children under 6				With children, none under 6			
					HS or less		College		HS or less		College		HS or less		College	
	Stand. model	SDM	Stand. model	SDM	Stand. model	SDM	Stand. model	SLX	Stand. model	SLX	Stand. model	SLX	Stand. model	SLX	Stand. model	SLX
Intercept	109.08**	50.45**	85.83**	57.06**	129.70**	116.40**	95.82**	68.53**	66.25**	36.39*	94.30**	121.18**	97.83**	88.23**	174.35**	140.06**
	(4.71)	(9.53)	(7.53)	(4.63)	(11.42)	(20.53)	(17.60)	(23.03)	(12.55)	(17.89)	(17.88)	(22.68)	(8.00)	(11.78)	(14.70)	(18.96)
Commute time (for men)	0.02	-0.02	0.04	-0.07	-0.13**	0.00	-0.01	0.01	-0.25**	-0.05	-0.31**	-0.12	-0.11**	-0.04	-0.31**	-0.16.
	(0.02)	(0.03)	(0.03)	(-1.57)	(0.05)	(0.07)	(0.07)	(0.11)	(0.05)	(0.07)	(0.07)	(0.11)	(0.03)	(0.05)	(0.06)	(0.09)
Log of residential land price	-1.98**	-1.28*	-1.36**	0.83	-3.57**	-1.57	-0.87	-3.93	-2.14*	-4.35*	-2.68*	-4.70	-2.36**	-2.62*	-7.62**	-9.17**
	(0.31)	(0.57)	(0.50)	(0.86)	(0.76)	(1.65)	(1.14)	(2.93)	(0.82)	(1.75)	(1.15)	(2.82)	(0.53)	(1.12)	(0.95)	(2.36)
Unemployment rate (for men)	0.35*	0.32*	0.35	0.44*	-0.81*	-0.61	-0.06	-0.69	-0.01	-0.03	-0.36	-0.22	0.07	0.10	0.51	0.55
	(0.14)	(0.13)	(0.23)	(2.04)	(0.34)	(0.34)	(0.53)	(0.59)	(0.36)	(0.36)	(0.54)	(0.57)	(0.25)	(0.25)	(0.45)	(0.48)
Households with two or more children	0.29**	0.16**	0.48**	0.38**	-0.61**	-0.43**	-0.47*	-0.72**	0.08	-0.03	-0.39*	-0.25	-0.03	-0.03	-0.23	-0.31
	(0.05)	(0.05)	(0.08)	(3.85)	(0.13)	(0.16)	(0.19)	(0.25)	(0.14)	(0.17)	(0.19)	(0.25)	(0.09)	(0.11)	(0.16)	(0.21)
Availability of childcare centers	-0.01	0.00	-0.01	0.02	-0.06	-0.05	-0.02	0.03	0.22**	0.16**	0.24**	0.39**	0.10**	0.06*	-0.04	-0.15**
	(0.01)	(0.01)	(0.02)	(0.93)	(0.03)	(0.04)	(0.07)	(0.09)	(0.03)	(0.04)	(0.07)	(0.08)	(0.02)	(0.02)	(0.05)	(0.05)
W × Commute time (for men)		0.03		0.13*		-0.19		-0.15		-0.37**		-0.42**		-0.08		-0.14
		(0.03)		(2.11)		(0.10)		(0.15)		(0.10)		(0.15)		(0.07)		(0.12)
W × Log of residential land price		0.57		-2.14		-1.72		5.01		4.63*		1.47		0.94		3.52
		(0.67)		(-1.91)		(1.89)		(3.28)		(2.01)		(3.10)		(1.30)		(2.60)
W × Unemployment rate (for men)		-0.03		-0.55		-0.30		2.14*		0.04		-0.39		-0.46		-0.29
		(0.26)		(-1.26)		(0.69)		(1.00)		(0.74)		(0.97)		(0.51)		(0.86)
W × Households with two or more children		0.08		-0.06		-0.12		0.47		0.52*		-0.22		0.14		0.43
		(0.08)		(-0.43)		(0.24)		(0.36)		(0.25)		(0.35)		(0.17)		(0.28)
W × Availability of childcare centers		-0.01		-0.02		-0.03		-0.17		0.12		-0.37**		0.12**		0.35**
		(0.02)		(-0.68)		(0.06)		(0.14)		(0.07)		(0.11)		(0.04)		(0.09)
ρ		0.48**		0.40**		0.20*										
		(0.07)		(0.08)		(0.09)										
N	243	243	243	243	239	239	206	206	238	238	209	209	243	243	218	218
Log-Likelihood	-571.8	-544.0	-686.0	-667.8	-768.1	761.4	-768.1	-713.0	-778.9	-767.9	-733.3	-723.9	-700.6	-694.1	-730.4	-718.2
LR test (SDM or SLX vs stand. model)		55.7**		36.2**		13.3**		110.3**		22.1**		18.9**		13.1*		24.3**

Note: The men and women in the samples are 25-54 years old. Standard errors are in parentheses. W is the binary contiguity matrix. Each sample excludes municipalities with populations of less than 50 people or no neighboring municipalities.
* $p < 0.05$,
** $p < 0.01$.

Table 5
Marginal effects of commute time on labor force participation rates.

	Total effect	Direct effect	Indirect effect	N
Married men	0.02	− 0.01	0.03	243
	(0.37)	(0.62)	(0.60)	
Unmarried women	0.11	− 0.06	0.17	243
	(1.41)	(− 1.44)	(1.95)	
Married women				
No children				
HS or less	− 0.23 **	− 0.01	− 0.23 *	239
	(− 2.65)	(− 0.12)	(− 2.12)	
College	− 0.13	0.01	− 0.15	206
	(− 1.18)	(0.14)	(− 0.97)	
With children under 6				
HS or less	− 0.41 **	− 0.05	− 0.37 **	238
	(− 5.47)	(− 0.62)	(− 3.52)	
College	− 0.54 **	− 0.12	− 0.42**	209
	(− 5.18)	(− 1.14)	(− 2.79)	
With children, none under 6				
HS or less	− 0.12 *	− 0.04	− 0.08	243
	(− 2.29)	(− 0.84)	(− 1.07)	
College	− 0.31 **	− 0.16	− 0.15	218
	(− 3.39)	(− 1.92)	(− 1.17)	

Note: t-values are in parentheses. W is the binary contiguity matrix.
* $p < 0.05$,
** $p < 0.01$.

time (the variable of interest) on the labor force participation rates in the SDM or SLX models, in accordance with the preferred models in Table 4.[9] The total effects differ markedly by marital status and the presence of children. For married men and unmarried women, the association between commute time and the participation rate is positive and nonsignificant. In contrast, for married women with children, commute time is negatively and significantly associated with the participation rate. For married women without children, the association is also negative and significant for those with a high school education or less, but is nonsignificant for college graduates.

Among married women with children (for both under 6 years old as well as 6 and above), the magnitude of the negative association is greater for college graduates than for those with a high school education or less. This result indicates that highly educated mothers are more sensitive to commute times when participating in the labor market. For college-educated married women with children under 6 years old, for instance, a one-minute increase in commute time is associated with a 0.54 percentage point decrease in the labor force participation rate. Since the range of commute times across municipalities is 46.2 min (see Table 1), the commute time difference results in a 24.9 percentage point difference in the labor force participation rate. This is not a small difference given that the range of the participation rate for these women is 64.6% (the maximum of 84.6% minus the minimum of 20.0%).

It is interesting to note that the direct effects are nonsignificant for all groups, suggesting that labor force participation is not significantly associated with commute time in one's own municipality. On the other hand, for childless married women with a high school education or less, and married women with children under 6 years old, the indirect effects (spillover effects) are significant. This result implies that for these groups of women, labor force participation is more responsive to commute time in neighboring municipalities than to commute time in one's own municipality. This could indicate that those women tend to work in the vicinity of their residences, and as a result, an increase in commute time in neighboring municipalities might be associated with a decrease in the labor force participation rate. For married women with children aged 6 and older, while the direct and indirect effects are both nonsignificant, the total effects are significant. This result indicates that the associations between commute time and labor force participation are significant when the impact of commute time combines the impact of commute time in one's own municipality with that of neighboring municipalities. In fact, for these women, the magnitude of the total effects is notably greater than that of the direct and indirect effects.[10]

When the total effects in the SDM or SLX models are compared with the coefficients (marginal effects) of commute time in the standard models (Table 4), the signs and significance are consistent. Compared with the coefficients in the standard models, the magnitude of the total effects in the SDM or SLX models is greater or almost the same. This result suggests that the associations between commute time and the labor force participation rate tend to become greater when the models incorporate the spatial dependence (spillovers).

Table 6 shows the estimation results of the standard models and the SDM or SLX models for regular employment rates. For married women with children under 6 years of age and college-educated married women with children aged 6 and older, the spatial autoregressive coefficients (ρ) are nonsignificant. For these groups of women, we also estimate the SLX models. Since the LR test statistics indicate SLX as a preferable specification to SDM, we report the results of the SLX models.

Except for childless married women with a high school education or less and college-educated married women with children under 6 years old, the values of the LR test of the SDM or SLX models versus the standard models exceed the 5% critical values (12.6 for the SDM models and 11.1 for the SLX model), indicating the SDM or SLX models as preferred alternatives. For childless married women with a high school education or less and for college-educated married women with children under 6 years old, the values of the LR test (7.8 and 9.4, respectively) are smaller than the 5% critical value, implying that the standard models need not be rejected in favor of the SDM or SLX model. For these two groups of women, the signs and significance of the total effects in the SDM or SLX model are consistent with those of the coefficients in the standard models, and the differences in the magnitude of the total effects and coefficients in the standard models are small.

Table 7 shows the total, direct, and indirect effects of commute time on the regular employment rates in the SDM or SLX models, corresponding to the preferred models in Table 6.[11] The total effects of commute time indicate notable differences by marital status and the presence of children. For unmarried women and married women without children, commute time is not significantly associated with the regular employment rate. For married women with children, on the other hand, commute time is negatively and significantly associated with the regular employment rate, except for married women with children aged 6 or older and high school education or less; for this group of women, the association is nonsignificant. When the sample is

[9] In fact, the total, direct, and indirect effects in the SLX models are similar to those in the SDM models (not presented).

[10] The total effect is the sum of the direct and indirect effects. For married women with children aged 6 and older, the total effect is −0.12 (the sum of −0.04 and −0.08) for those with a high school education or less, and is −0.31 (the sum of −0.16 and −0.15) for those with a college education. The significant total effect indicates that the total effect is significantly different from zero, while the direct and indirect effects are not.

[11] As in the case of labor force participation, the total, direct, and indirect effects in the SLX models are similar to those in the SDM models (not presented).

Table 6
Regression of regular employment.

	Unmarried women		Married women											
			No children				With children under 6				With children, none under 6			
			HS or less		College		HS or less		College		HS or less		College	
	Stand. model	SDM	Stand. model	SDM	Stand. model	SDM	Stand. model	SLX	Stand. model	SLX	Stand. model	SDM	Stand. model	SLX
Intercept	44.15**	35.26**	42.49**	40.81**	73.29**	70.36*	42.03**	42.11**	76.89**	112.69**	39.81**	27.31**	122.50**	113.05**
	(8.32)	(11.72)	(9.49)	(14.16)	(21.69)	(27.64)	(7.76)	(11.28)	(17.34)	(22.49)	(5.80)	(8.94)	(16.73)	(22.09)
Commute time (for men)	0.11**	0.12*	-0.06	-0.02	-0.06	0.09	-0.11**	0.00	-0.16*	-0.07	-0.10**	-0.06	-0.32**	-0.16
	(0.04)	(0.05)	(0.04)	(0.06)	(0.09)	(0.13)	(0.03)	(0.05)	(0.07)	(0.11)	(0.02)	(0.03)	(0.07)	(0.10)
Log of residential land price	-0.44	-0.09	-0.90	-0.42	-0.70	-1.17	-1.51**	-2.43*	-2.31*	0.57	-1.58**	-2.34**	-6.79**	-9.71**
	(0.55)	(1.07)	(0.63)	(1.38)	(1.41)	(3.41)	(0.51)	(1.10)	(1.12)	(2.80)	(0.39)	(0.78)	(1.09)	(2.75)
Unemployment rate (for men)	-0.97**	-0.73**	-0.45	-0.35	-1.13	-1.46*	-0.81**	-0.74**	-0.43	0.20	-0.09	-0.11	-0.34	-0.10
	(0.26)	(0.24)	(0.28)	(0.28)	(0.65)	(0.68)	(0.22)	(0.23)	(0.53)	(0.57)	(0.18)	(0.17)	(0.51)	(0.56)
Households with two or more children	0.36**	0.16	-0.36**	-0.25	-0.60*	-0.57	-0.24**	-0.19	-0.72**	-0.48	-0.30**	-0.18*	-0.27	-0.12
	(0.09)	(0.11)	(0.11)	(0.13)	(0.24)	(0.30)	(0.08)	(0.11)	(0.19)	(0.25)	(0.06)	(0.08)	(0.18)	(0.24)
Availability of childcare centers	0.03	0.08**	0.01	0.01	-0.07	-0.12	0.04*	0.02	0.04	0.05	0.10**	0.07**	0.19**	0.08
	(0.02)	(0.02)	(0.03)	(0.03)	(0.09)	(0.11)	(0.02)	(0.03)	(0.07)	(0.08)	(0.01)	(0.02)	(0.06)	(0.06)
W × Commute time (for men)		-0.12		-0.05		-0.34		-0.18**		-0.15		0.00		-0.15
		(0.07)		(0.08)		(0.18)		(0.07)		(0.15)		(0.05)		(0.14)
W × Log of residential land price		-0.22		-0.65		1.80		1.29		-4.60		1.33		3.59
		(1.23)		(1.57)		(3.81)		(1.26)		(3.07)		(0.92)		(3.02)
W × Unemployment rate (for men)		-0.50		-0.21		2.88*		-0.42		-2.33*		0.10		-0.96
		(0.49)		(0.58)		(1.17)		(0.47)		(0.96)		(0.35)		(1.00)
W × Households with two or more children		0.24		-0.09		-0.25		-0.01		-0.34		-0.10		-0.09
		(0.16)		(0.20)		(0.43)		(0.16)		(0.35)		(0.12)		(0.33)
W × Availability of childcare centers		-0.10*		-0.01		-0.08		0.04		-0.01		0.04		0.29**
		(0.04)		(0.05)		(0.16)		(0.04)		(0.11)		(0.03)		(0.10)
ρ		0.34**		0.23*		-0.28**						0.22*		
		(0.08)		(0.09)		(0.11)						(0.09)		
N	243	243	239	239	206	206	238	238	209	209	243	243	218	238
Log-Likelihood	-710.3	-690.6	-723.8	-719.9	-760.3	-751.4	-664.5	-658.0	-726.8	-722.1	-622.6	-613.4	-758.6	-751.5
LR test (SDM or SLX vs stand. model)		39.4**		7.8		17.8**		13.0*		9.4		18.5**		14.2*

Note: The men and women in the samples are 25-54 years old. Standard errors are in parentheses. *W* is the binary contiguity matrix. Each sample excludes municipalities with populations of less than 50 people or no neighboring municipalities.
* $p < 0.05$,
** $p < 0.01$.

for married women with children in general (not shown in Table 7), the total effect is negative and significant (−0.10 with a *t*-value of −2.02).[12]

Among married women with children, the negative associations between commute time and the regular employment rate are greater in absolute values for college graduates than for those with a high school education or less, as in the case of labor force participation. For college-educated married women with children aged 6 or older, for example, a one-minute increase in commute time is associated with a 0.32 percentage point decrease in the regular employment rate. Incorporating the range of commute time (46.2 min) results in a 14.8 percentage point difference in the regular employment rate.

Interestingly, the direct effect is significant and positive for unmarried women, while the direct effects for the other groups of women are all nonsignificant and mostly negative. This pattern could indicate that unmarried women have lower spatial constraints than married women; unmarried women might be able to travel longer to work as regular employees. For married women with children under 6 years of age and a high school education or less, the indirect effect is significant, whereas the direct effect is nonsignificant. This implies that these women are more responsive to commute times in neighboring municipalities than to commute time in their own municipality. This might be partly because those women are likely to work in nearby municipalities as regular employees. For college-educated married women with children (under 6 years of age as well as 6 and above), the total effects are significant, while both the direct and indirect effects are nonsignificant. This result suggests that for these college-educated women, commute time is

[12] The total effect is estimated with the SDM since the autoregressive coefficient is significant.

Table 7
Marginal effects of commute time on regular employment rates.

	Total effect	Direct effect	Indirect effect	N
Unmarried women	− 0.01 (− 0.15)	0.11 * (2.47)	− 0.12 (− 1.37)	243
Married women				
No children				
HS or less	− 0.09 (− 1.16)	− 0.02 (− 0.36)	− 0.07 (− 0.75)	239
College	− 0.19 (− 1.82)	0.11 (0.78)	− 0.30 (− 1.73)	206
With children under 6				
HS or less	− 0.18 ** (− 3.85)	0.00 (0.00)	− 0.18 ** (− 2.78)	238
College	− 0.23 * (− 2.17)	− 0.07 (− 0.69)	− 0.15 (− 1.02)	209
With children, none under 6				
HS or less	− 0.08 (− 1.74)	− 0.06 (− 1.80)	− 0.02 (− 0.40)	243
College	− 0.32 ** (− 2.99)	− 0.16 (− 1.64)	− 0.15 (− 1.07)	218

Note: *t*-values are in parentheses. *W* is the binary contiguity matrix.
* $p < 0.05$,
** $p < 0.01$.

significantly associated with regular employment rates when the impact of commute time combines that in one's own municipality with that in neighboring municipalities (spatial spillovers).[13]

When we compare the total effects with the coefficients in the standard models (Table 6), the sign and significance are mostly consistent. The differences are for unmarried women and for married women with children aged 6 or older as well as a high school education or less; for these groups of women, the coefficients in the standard models are significant but the total effects in the SDM are nonsignificant.

We do not present the results for part-time employment rates since their associations with commute time are mostly nonsignificant.

The household division of labor hypothesis is most relevant when one spouse (husband) makes a long commute and the other spouse (wife) makes a short commute or stays home. While many of the suburban municipalities in our sample seem to fit this pattern, there are some for which the commuting distance from the CBD is so long that the household division described above is less likely to hold. To address this concern, we estimate our models using the sample of municipalities in which 10% or more of male commuters travel to the CBD for work. The results are presented in Appendices A and B. Figs. A1 and A2 show the corresponding maps for male commute times and the female labor force participation and regular employment rates, respectively. The spatial patterns of the hot and cold spots are largely consistent with those for the entire metropolitan area, except for the regular employment rate for married women with children (Fig. A2(f)). For these married mothers, hot spots of the regular employment rate appear in the CBD, while the hot spots are non-existent in the CBD for the sample of the entire metropolitan area (Fig. 2(f)).

The estimated total, direct, and indirect effects of commute time on female labor force participation and regular employment rates in the SDM or SLX models are reported in Tables B1 and B2, respectively. Each sample excludes municipalities with populations of less than 50 people or no neighboring municipalities. The results of the SLX models are presented when the autoregressive coefficients (ρ) in the SDM models are nonsignificant and when the LR test values indicate the SLX models as preferable to the SDM models. The results are largely consistent with those for the entire metropolitan area. For the labor force participation rates, the signs and significance of the total effects remain the same. For the regular employment rates, the signs are consistent but the significance shows some changes. The changes, however, do not alter the finding that the associations between commute time and the regular employment rates are negative and significant for married women with children. Of note is that the magnitude and significance of the total effects for college-educated married women are greater than those for the samples of the entire metropolitan area (Table 7). This result suggests that within the commuting distance from the CBD, highly educated women who work as regular employees are particularly sensitive to commute time.

5. Conclusions

Our municipal-level analysis revealed considerable intra-metropolitan disparities in female labor force participation, regular employment, and part-time employment rates. As implied by the Global Moran's I statistics, these rates are not evenly distributed within the metropolitan area. There are spatial clusters of high and low rates. The hot and cold spot maps show that the spatial patterns of the labor force participation and regular employment rates differ markedly by marital status and the presence of children. Compared with unmarried women and married women without children, married women with children exhibit more significant spatial clustering of high and low rates of labor force participation and regular employment. For married mothers, the spatial clusters of low participation and regular employment rates are largely located in the inner suburbs, many of which overlap with the spatial clusters of long male commute times.

The spatial regression results indicate that for married mothers, a longer commute is significantly associated with lower labor force participation and regular employment rates, while for unmarried and childless married women, the associations are mostly nonsignificant. The findings support the view that mothers' labor market participation is sensitive to commute time. Since residential decisions are endogenous, the effect of commute time on participation is not causal. Rather, the circumstances in the Tokyo metropolitan area induce households to simultaneously decide location and labor market participation for both spouses. The typical choices are: (1) living close to the CBD and both spouses work there; (2) living in the inner suburbs, whereby the husband commutes to the CBD and the wife stays home or works locally; and (3) living in the outer suburbs and both spouses work in the suburbs.

The spatial regression results also indicate that among married mothers, the negative associations between commute time and the labor force participation and regular employment rates are greater for college graduates than for those with a high school education or less. These findings differ from those of Black et al. (2014), who find greater associations for high school graduates than for college graduates among married women.[14] These contradictory results may have arisen partly because our study is based on intra-metropolitan data, while the study by Black et al. (2014) is based

[13] For college-educated married women, the total effect is −0.23 (the sum of −0.07 and −0.15, not −0.22 due to rounding) for those with children under 6, and is −0.32 (the sum of −0.16 and −0.15, not −0.31 due to rounding) for those with children aged 6 and older. The total effect is markedly larger than the direct and indirect effects, in absolute values. The significant total effect denotes that the total effect is significantly different from zero, whereas the direct and indirect effects are not.

[14] In a model for women with children under 5 in the study by Black et al. (2014, Panel B2 in Table 6, p. 68), the association is greater for college than for high school graduates, but in all other models, including married women in general, the associations are greater for high school than college graduates.

on inter-metropolitan data. In the inter-metropolitan analysis, highly educated women are perhaps more likely to live and work in larger metropolitan areas where they have longer commute times. In contrast, in our intra-metropolitan analysis of Tokyo, highly educated women are more likely to live and work closer to the CBD, with shorter commute times.

Our findings imply that for married mothers, intra-metropolitan disparities in commute times play an important role in their participation in the labor market. The inner suburbs, which are farther from the CBD but from where men nonetheless regularly commute, have high concentrations of lower labor force participation and regular employment rates for married mothers. Since commute time is not significantly associated with the labor force participation rate for married men (see Table 4), suburban living that entails a long commute for the father intensifies the household division of labor in which the father travels to the CBD and the mother either stays home or works locally. We argue that the spatial transportation constraint induces this gender division, resulting in unique patterns for married mothers.

In many countries, among women with children, preferences for participation in the labor market are much higher than actual participation rates (Jaumotte, 2003). A national survey in Japan shows that among couples with children under 15, most women (86%) who are not currently working would want to (National Institute of Population and Social Security Research, 2016). Our findings suggest that implementing policies, which alleviate commuting constraints, could help women with children participate more actively in the labor market. Examples include improving employment accessibility, reducing congestion, promoting flexible working hours, increasing the housing supply around employment centers, and encouraging male commitment to do housework and childcare.

In recent years, the number of dual-earner couples in Japan has risen dramatically. Spatio-temporal analysis using data after 2010 is a possible direction for further research. Another is to conduct a comparative analysis of Tokyo and other metropolitan areas. Our research revealed that within a metropolitan area, the levels of female participation differ by location, and the intra-metropolitan disparities have unique spatial patterns. Spatially disaggregated analysis potentially unveils important dimensions of the urban labor market that deserve more attention.

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Appendix A

(See Figs. A1 and A2).

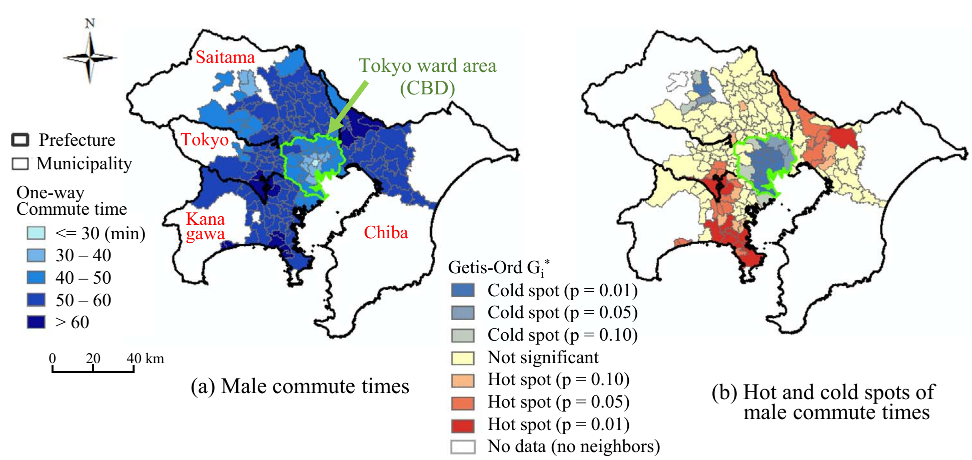

Fig. A1. Male commute times for municipalities in which 10% or more of male commuters travel to the Tokyo ward area to work.
Note: The men are 25-54 years old

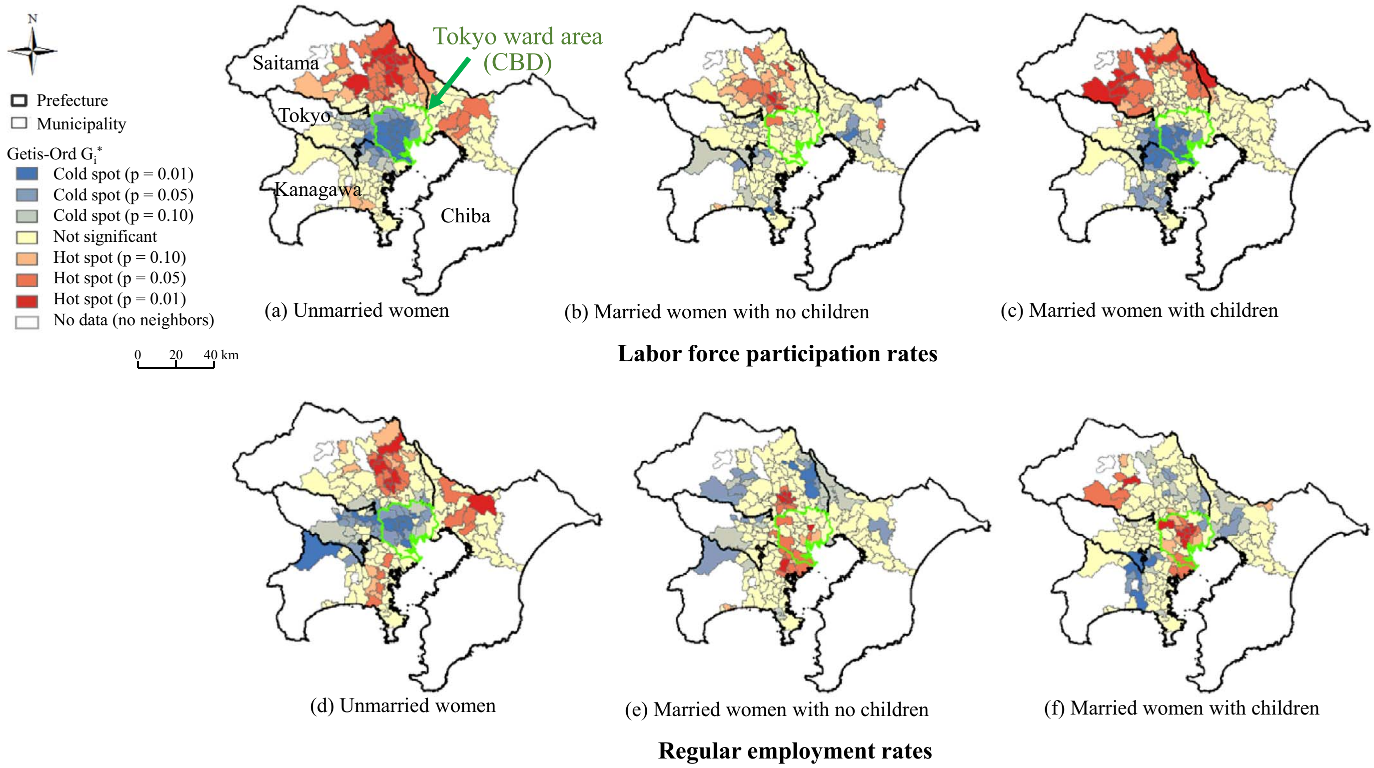

Fig. A2. Hot and cold spots of female labor force participation and regular employment rates for municipalities in which 10% or more of male commuters travel to the Tokyo ward area to work.
Note: The women are 25-54 years old.

Appendix B

(See Tables B1 and B2).

Table B1
Marginal effects of commute time on labor force participation rates for municipalities in which 10% or more of male commuters travel to the Tokyo ward area for work.

	Total effect	Direct effect	Indirect effect	*N*	Model
Unmarried women	− 0.05 (− 0.54)	0.02 (0.33)	− 0.07 (− 0.63)	162	SDM
Married women					
No children					
HS or less	− 0.20* (− 2.06)	0.10 (0.78)	− 0.30 (− 1.82)	162	SLX
College	− 0.17 (− 1.63)	− 0.01 (− 0.08)	− 0.16 (− 0.90)	160	SLX
With children under 6					
HS or less	− 0.33** (− 3.96)	0.11 (0.82)	− 0.44** (− 2.72)	162	SDM
College	− 0.50** (− 5.23)	0.00 (0.03)	− 0.50** (− 2.82)	161	SDM
With children, none under 6					
HS or less	− 0.23** (− 3.36)	− 0.25** (− 2.76)	0.02 (0.13)	162	SLX
College	− 0.26* (− 2.03)	− 0.18 (− 1.31)	− 0.08 (− 0.45)	162	SDM

Note: *t*-values are in parentheses. *W* is the binary contiguity matrix.
* $p < 0.05$,
** $p < 0.01$.

Table B2
Marginal effects of commute time on regular employment rates for municipalities in which 10% or more of male commuters travel to the Tokyo ward area for work.

	Total effect	Direct effect	Indirect effect	*N*	Model
Unmarried women	− 0.13	0.12	− 0.25*	162	SDM
	(− 1.56)	(1.45)	(− 2.14)		
Married women					
No children					
HS or less	− 0.06	− 0.02	− 0.04	162	SDM
	(− 0.66)	(− 0.22)	(− 0.30)		
College	− 0.29*	− 0.06	− 0.22	160	SLX
	(− 2.23)	(− 0.37)	(− 1.03)		
With children under 6					
HS or less	− 0.11	0.06	− 0.18	162	SLX
	(− 1.94)	(0.83)	(− 1.78)		
College	− 0.39**	0.16	− 0.55**	161	SLX
	(− 4.35)	(1.18)	(− 3.30)		
With children, none under 6					
HS or less	− 0.15**	− 0.02	− 0.13	162	SLX
	(− 3.79)	(− 0.44)	(− 1.90)		
College	− 0.36**	0.03	− 0.39**	162	SLX
	(− 4.28)	(0.25)	(− 2.72)		

Note: *t*-values are in parentheses. *W* is the binary contiguity matrix.
* $p < 0.05$,
** $p < 0.01$.

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