Spatial dimensions of intra-metropolitan disparities in commuting time and female labor force participation

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We examine intra-metropolitan patterns of geographic disparities in female participation in the labor market and their associations with commuting time in the Tokyo metropolitan area. Our analysis based on the Global Moran's I and Getis-Ord G_i^* statistics reveals that the spatial patterns of 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 values of labor force participation and regular employment rates, and these rates are negatively correlated with male commuting time. The non-spatial and spatial regression results show that for married women with children, longer commuting time is significantly associated with lower participation and regular employment rates, while for unmarried women and married women without children, the associations are mostly insignificant. These results are robust to different model specifications and spatial weights. Our findings suggest that policies alleviating commuting constraints help women with children in dual-earner couples more actively participate in the labor market.

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1. Introduction

Making a long commute to one's job is one of the most stressful urban activities around the world. In a large metropolitan area like Tokyo, many people spend extended time commuting via heavily congested public transportation. It is conceivable that women in particular dislike spending time making such a commute. Besides, many parents with young children must take them to childcare facilities, adding extra time spent commuting between home and childcare facilities before going to work in the morning and after leaving work in the evening. Although greater participation by women in the labor market has been an important policy agenda in many countries including Japan (OECD, 2012; CAO, 2016), spatial dimensions of the difficulties in female participation have not been understood well. In this paper, we ask: (1) to what degree intra-metropolitan geographic disparities exist in female participation in the labor market; (2) whether any spatial regularity exists in such geographical disparities, and (3) whether the disparities are related to male commuting time. We examine these questions for women aged 25-54 years in Tokyo, the world's most populated metropolitan area.

Geographic disparities in female participation in the labor market have attracted increasing attention. Recent studies show that female participation differs considerably across regions, such as metropolitan areas, counties, and prefectures (Abe, 2011; Fogli and Veldkamp, 2011; Black et al., 2014). Several argue that commuting time is an important factor explaining the large geographic variations in female participation (Abe, 2011; Black et al., 2014). Empirical evidence on the influence of commuting time on female participation is limited, however. Using commuting time at the level of US metropolitan areas, Black et al. (2014) find negative associations between commuting time and labor force participation of married women. The *intra*-metropolitan spatial patterns of female participation and their associations with commuting time, however, have not been well understood. The level of female participation is unlikely to be evenly distributed within a metropolitan area. For example, married women with children who need more housing space may live disproportionately in the suburbs, which offer lower housing costs; such women are more likely to be housewives or work part time, rather than work full time and commute to the central business district (CBD), assuming that full-time jobs are more abundant in the CBD. In contrast, households in which both spouses work in the CBD have greater incentives to reside close to the CBD and perhaps endure smaller dwelling size.

The purpose of this research is to shed new light on the geographic disparities in female participation by examining intra-metropolitan spatial patterns and studying whether they are related to male commuting time. It is known that female commuting is shorter than male commuting (this point is reviewed in the next section). The shorter commuting time for women suggests that making a long commute is not feasible for women, either because they face greater spatial constraints or they have stronger preferences for short commutes. It is conceivable that long commutes in large metropolitan areas impede many women from participating in the labor market.

The contribution of this paper is three-fold. First, we examine the three groups of women aged 25-54 years—unmarried women, married women with children, and married women without children, and the rates for the three types of female participation in the labor market—labor force participation, regular employment, and part-time employment. A comparison of women in the three demographic groups and the three types of female participation is rare in the literature. Second, we use data at the municipal level, a more disaggregated spatial unit than inter-metropolitan data used in the previous research (Black et al., 2014). The use of the smaller geographical unit is important for this study, as commuting time could differ significantly across locations within the metropolitan area. We are unaware of research that examines municipal-level female participation vis-à-vis commuting time using Japanese data. Examining municipal data within a metropolitan area allows us to examine the role of commuting time in an environment where relocation (sorting by choosing residential location) is more realistic. It may be unlikely that people migrate to Minneapolis from New York City, for example, because commuting cost is lower in the former. However, it is likely that people choose from locations within the Tokyo metropolitan area (e.g., Kamakura versus central Tokyo) when considering commuting distance and housing costs of each. Finally, we employ geographic information systems (GIS) to visualize the spatial patterns on the maps and use spatial statistics—the Global Moran’s I and Getis-Ord G_i^* statistics, as well as spatial regression models—to examine the spatial patterns of female participation and their associations with commuting time. GIS and spatial statistics have not been applied much in previous research on female participation.

We find that considerable geographic disparities exist in female participation. We also find that the spatial patterns of 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 have more significant spatial clustering of high and low values of labor force participation and regular employment rates, and these rates are more negatively and significantly associated with male commuting time.

The next section provides a review of the related literature. Section 3 explains the methods including a description of the study area and data. Section 4 presents the results, 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). Commuting time is short for married women, especially when they have children, whereas it is long for married men, even when they have children (Madden, 1981; McLafferty and Preston, 1997; Hjorthol, 2000; Rapino and Cooke, 2011).

Researchers examine various explanations of why women work closer to home than do men. Many scholars argue that the gender disparity in commuting reflects the household division of labor in which women shoulder more housework and childcare than do men (e.g., Maddden, 1981; McLafferty and Preston, 1997). This argument is often referred to as the household responsibility hypothesis (HRH) (e.g., Johnston-Anumonwo 1992; Turner and Neimeier, 1997). Indeed, evidence suggests that although the gender gap is narrowing, women do more domestic work than men do (Shelton and John 1993; Lennon and Rosenfield, 1994: Bianchi et al., 2012), even within dual-earner households in which both men and women work full-time (Hersch and Stratton, 1994). Empirical results of the HRH are mixed, however. Some support the HRH (Hanson and Hanson, 1980; Turner and Niemeier, 1997; Neto et al., 2015), while others show little or mixed evidence supporting the HRH (Hanson and Johnston, 1985; Gordon et al., 1989; Shingell and Lillydahl, 1986). Turner and Neimeier (1997) provide a critical review of the HRH.

Other explanations also exist for women's shorter commutes. Women tend to have lower wages, higher job turnover rates, and shorter work hours, which reduce economic incentives for long commuting (Madden, 1981; White, 1986; MacDonald, 1999). Differences in the spatial distributions of jobs suitable for women and men may partly explain the gender disparities in commuting (Hanson and Johnston, 1985; Hanson and Pratt, 1995; MacDonald, 1999). Women make more family support trips than do men, and women are more likely to combine non-work trips with work trips (Hanson and Hanson, 1981; Hanson and Johnston, 1985; Rosenbloom, 1987; McGuckin and Murakami, 1999; Hjorthol, 2000). The gender difference in the trip-chaining behavior is particularly noticeable when children are present. McGuckin and Murakami (1999) show 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) find that within households with children, women make considerably more chauffeuring trips than do men, while non-work trips of men and women do not differ much when they do not have children. These studies suggest that mothers are more sensitive to commuting time than men and women without children.

The sensitivity to commuting time is likely to be particularly severe for women with young children. Traveling with young children is not the same as traveling alone or traveling with adults. When commuting involves travels with infants and toddlers, mobility becomes limited, and spatial constraint increases in severity. Commuting may even involve unexpected trips to and from a hospital when a child falls sick. Roberts et al. (2011) show that commuting time has a negative influence on the psychological health of women, particularly for those who have preschool-aged children. They find no such negative effect for women and men who are single without children, working with flexible hours, or with partners performing most of childcare. Their study suggests that women who do more child rearing and household work have a greater psychological barrier to long commuting than those who have less domestic work.

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

Basic urban models indicate that housing and commuting costs are closely related with 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 further the distance from a CBD, the lower the housing prices and the higher the commuting cost. This pattern is found in metropolitan areas around the world, although actual specific patterns are more complex.

The intra-metropolitan differences in housing and commuting costs may be significantly associated with intra-metropolitan differences in female participation. Madden (1981) finds that compared with unmarried women, married women reside in larger houses and in locations further from the city center. She argues that married women are more residentially immobile than unmarried women. Married women consider not only their preferences but also the opinions of their husbands when selecting residential location. Those who have children also take into account residential environments beneficial for their children, such as schools and neighborhoods (Gamsu, 2016). Most women are secondary wage earners who have less bargaining power within households. Kain (1962) notes that such women are more likely to select their employment locations conditioned by selecting their residential location than are primary wage earners (i.e., men). Several studies suggest that dual-earner couples select their residential location based more on men’s workplaces than women’s (Madden, 1981; Singell and Lillydahl, 1986).

Hjorthol (2000) shows that in Oslo, commuting of married women and men is the shortest in the central parts of the region. In the Tokyo metropolitan area, many suburban workers commute to the central city, and their commuting time is especially lengthy. Of persons 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 great majority (80%) of the suburbs-to-CBD commuters use public transportation (TMRTPC, 2010). Trains and buses are heavily congested during rush hours. Long commuting in heavily congested trains and buses may inhibit many women from fully participating in the labor market.

3. Methods

3.1 Intra-metropolitan patterns of female participation and commuting time

The spatial patterns of female participation in the labor market and commuting time are examined by calculating Global Moran’s I and Getis-Ord G_i^* statistics. The Global Moran’s I statistic (Moran, 1950) is a global measure of spatial autocorrelation. In this study, the Moran’s I statistics are used to evaluate whether the spatial patterns of commuting time and the three participation measures (female labor force participation, regular employment, and part-time employment rates) are random, clustered, or dispersed. The Moran’s I value (I) is calculated as:

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

where n is the number of spatial units indexed by i and j, x denotes the variable of interest, $\bar{X}$ is the mean of x, and $w_{i,j}$ indicates the spatial weight between i and j. The z-score for the Moran’s I is given as:

$$z_I = \frac{I - E[I]}{\sqrt{E[I^2] - E[I]^2}}, \tag{2}$$

where

$$\mathrm{E[I]} = \frac{-1}{n-1}, \tag{3}$$

$$\mathrm{E}[I^2] = \frac{n\left[(n^2 - 3n + 3)S_1 - nS_2 + 3S_0^2\right] - \frac{\sum_{i=1}^{n} z_i^4}{\left(\sum_{i=1}^{n} z_i^2\right)^2}\left[(n^2 - n)S_1 - 2nS_2 + 6S_0^2\right]}{(n-1)(n-2)(n-3)S_0^2}, \tag{4}$$

$$S_0 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}, \tag{5}$$

$$S_1 = \left(\frac{1}{2}\right)\sum_{i=1}^{n}\sum_{j=1}^{n}\left(w_{i,j} + w_{j,i}\right)^2, \tag{6}$$

$$S_2 = \sum_{i=1}^{n}\left(\sum_{j=1}^{n} w_{i,j} + \sum_{j=1}^{n} w_{j,i}\right)^2. \tag{7}$$

The null hypothesis is that the values being analyzed are randomly distributed across space (or no spatial autocorrelation). If the Moran’s I statistics are significant, a negative Moran’s I value indicates spatial dispersion, and a positive Moran’s I value denotes spatial clustering. Note that the Moran’s I value is a *global* measure, i.e., a single measure for a study area as a whole (the Tokyo metropolitan area in this study) and does not evince the locations of spatial clustering within the study area.

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

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \bar{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}}, \tag{8}$$

where

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n}, \tag{9}$$

$$\mathrm{S} = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{X})^2}\ . \qquad (10)$$

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. When the G_i^* statistic is positive and significant, a larger statistic indicates more intense clustering of high values (hot spots). When the G_i^* statistic is negative and significant, a smaller statistic denotes more intense clustering of low values (cold spots). In this study, the conventional 5% significance level is used to determine the hot spots and cold spots. (Municipalities with G_i^*statistics greater than 1.96 are regarded as hot spots, and municipalities with G_i^*statistics less than -1.96 are referred to as cold spots.) Using GIS, we plot the G_i^* statistics on maps to examine the spatial patterns of hot and cold spots visually.

The spatial weight for the Moran's I and G_i^* statistics is specified based on the first-order binary contiguity matrix (often called queen contiguity), where two spatial units are defined as neighbors when they share a common border or a common vertex. The contiguity matrix is a commonly used spatial weights matrix for data represented by areal units (polygons) that vary in size. Other spatial weights are also used to examine whether the results are sensitive to the choice of weights. In calculating the Moran's I statistics, the row elements of the spatial weights matrix are standardized so that their sum equals one. For the G_i^* statistics, the row standardization does not matter; resultant statistics with and without the row standardization are the same.

3.2 Non-spatial and spatial models

Regression models are estimated to examine the relationships between commuting time and the three participation measures. First, we estimate the regression models with ordinary least squares (OLS), which is a non-spatial specification. If diagnostic tests suggest the presence of spatial dependence, then we also estimate spatial lag or spatial error models (spatial models), each of which is explained below.

The spatial lag model, also known as the mixed regressive spatial autoregressive model, incorporates a spatially lagged dependent variable in addition to exogenous explanatory variables on the right hand of regression equation (Ord, 1975; Anselin, 1988). The specification is as follows:

$$\mathbf{y} = \rho \mathbf{W} \mathbf{y} + \mathbf{X} \beta + \mathbf{u}, \qquad (11)$$

where $\mathbf{y}$ is a vector of observations on the dependent variable, $\mathbf{W}$ represents a spatial weights matrix, $\mathbf{Wy}$ is the spatial lag term (spatially lagged dependent variable) with the spatial autoregressive parameter ρ, $\mathbf{X}$ indicates a matrix of observations on exogenous explanatory variables with a coefficient vector β, and $\mathbf{u}$ is a vector of error terms.

The spatial lag models are estimated with the spatial two stage least squares (S2SLS), which applies the concepts of two stage least squares (2SLS) to the spatial lag model (Anselin, 1988, 2014;

Kelejian and Robinson, 1993) and also with the maximum-likelihood (ML) estimation (Ord, 1975; Anselin, 1988). The S2SLS estimation uses the spatially lagged explanatory variables as instruments to correct for the endogeneity of a spatial lag term and uses first order spatial lags for the instruments. Standard errors of coefficients are computed with robust variance estimates that take into account heteroscedasticity (the White variance).

The spatial error model incorporates spatial dependence in error terms (Ord, 1975; Anselin, 1988). The model can be specified as follows:

$$\mathbf{y} = \mathbf{X}\beta + \mathbf{u}, \tag{12}$$

$$\mathbf{u} = \lambda\mathbf{W}\mathbf{u} + \epsilon, \tag{13}$$

where $\mathbf{u}$ is the vector of error terms that follows a spatial autoregressive process, λ denotes the spatial autoregressive parameter, $\mathbf{W}$ is the spatial weights matrix, and ϵ presents a vector of error terms. The spatial error models are estimated using the generalized method of moments (GMM) with heteroscedastic errors (Arraiz et al., 2010; Kelejian and Prucha, 2010; Drukker et al., 2013) and using the ML estimation (Anselin, 1988).

The spatial weights matrix $\mathbf{W}$ is specified based on the first-order binary contiguity matrix. The row elements of the spatial weights matrix are standardized so that their sum equals one. We also experiment with different spatial weights to see whether the results are robust.

Whether to estimate the spatial lag or spatial error model is determined based on the Lagrange Multiplier (LM) test statistics (Anselin, 1988, 2014; Anselin and Rey, 1991). The null hypothesis of the LM test for spatial lag is no spatially lagged dependent variable. The null hypothesis of the LM test for spatial error is no spatially autocorrelated error term. We follow the specification search suggested by Anselin (2014, pp. 109-111). If the LM statistics for spatial lag (LM_ρ) and spatial error (LM_λ) are both insignificant, neither the spatial lag nor the spatial error model is estimated. If LM_ρ is significant but LM_λ is insignificant, the spatial lag model is estimated. Conversely, if LM_λ is significant but LM_ρ is insignificant, the spatial error model is estimated. If both LM_ρ and LM_λ are significant, we see the robust LM statistics for lag (LM_ρ*) and error (LM_λ*). If LM_ρ* is more significant than LM_λ*, the spatial lag model is estimated. Conversely, if LM_λ* is more significant than LM_ρ*, the spatial error model is estimated. The conventional p-value of 0.05 is used to determine whether the statistics are significant.

In the spatial error model, the average marginal effect of an explanatory variable equals the coefficient estimate of that variable. For the spatial lag models, on the other hand, the marginal effect does not equal the total effect, due to the presence of indirect effect. In the spatial lag models, the value for the dependent variable at a given location is associated not only with the values for the explanatory variables at that location (direct effect) but also with the values for the explanatory variables at neighboring locations (indirect effect). The total effect is the sum of the direct and indirect effects. The coefficient estimate in a spatial lag model represents the direct effect. The total effect of a unit change in an explanatory variable is computed as $\hat{\beta}/(1-\hat{\rho})$, and the indirect effect is the difference between the total effect and direct effect (Kim, 2003; Anselin, 2014).

3.3 The study area and data

The study area is the Tokyo metropolitan area comprised of Tokyo Metropolis (the metropolitan prefecture) and its three neighboring prefectures—Chiba, Kanagawa, and Saitama. In terms of population, the Tokyo metropolitan area is the largest in the world, inhabited by 35.6 million people in 2010. Although several sub centers do exist, Tokyo's urban spatial structure has features of a monocentric city. The metropolitan area has a core, the Tokyo ward area, which is comprised of 23 special wards with densely concentrated population and business districts. In this study, the Tokyo ward area is regarded as the CBD.

The spatial unit of the analysis is the municipality (Shi, Ku, Mura, and Machi) in 2010, which is the smallest level of spatial detail available for the 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 or more in order to minimize sampling errors in participation statistics. As a result, the number of observations (municipalities) is 243 or less, depending on the sample.

Commuting time in this study is the average one-way travel time from home to work by municipality of residence, in minutes. Data on commuting time for men and women aged 25-54 years are from the special tabulations of the Tokyo Metropolitan Region Person Trip Survey in 2008. The survey is conducted every ten years, and the year 2008 is closest to 2010, the year of the labor force data. The special tabulations are obtained from the Tokyo Metropolitan Region Transportation Planning Commission (TMRTPC).

Data on labor force participation and regular and part-time employment for women aged 25-54 years by marital status, the presence of children, and education are from both publicly-available and order-made tabulations of the 2010 Population Census. The order-made tabulations are provided by the National Statistics Center of Japan. 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 one of the labor force participation, regular employment, or part-time employment rates. The independent variables are commuting time, the variable of our interest, and control variables. Commuting time is the average one-way commuting time for men (in minutes), as explained above. Since most men work, the use of male commuting time is likely to alleviate selection bias arising from the use of female commuting time.[1] Men and women in our data are 25 to 54 years old, unless otherwise noted.

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

The control variables include local housing prices, local income, and local unemployment rates for men, which are suggested as possible explanations for the large spatial variations in labor force participation of married women by Black et al. (2014); and two additional variables: proportion of households with two or more children and availability of childcare centers. Including the availability of childcare centers is important for this study since it is found to be a significant factor 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 Needs database.[2] 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-aged population are from the 2010 Population Census.

4. Empirical results

4.1 Spatial disparities in commuting time and female participation

Table 1 presents summary statistics of commuting time (average one-way commuting time) and the labor force participation, regular employment, and part-time employment rates.

Commuting time is shorter for women than for men: the median of commuting time is 38.8 minutes for women and 49.9 minutes for men. Shorter commuting time for women is observed throughout the world, but commuting time in Tokyo is considerably lengthy, even for women. For both men and women, commuting time has marked spatial dispersion. Commuting time varies from 11.7 to 59.7 minutes for women and from 21.4 to 67.6 minutes for men, with a standard deviation of 9.2 for women and 10.4 for men.

Female labor force participation, regular employment, and part-time employment rates differ by marital status and by the presence of children. Compared with unmarried women, married women without children are less likely to participate in the labor market and work as regular employees, and married women with children are even less likely to participate in the labor market

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[2] In the regression models, the log of the average residential land price is used. As a measure for local income, we could use 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. Average annual income per person, is not included in regressions, however, since it is highly correlated with average residential land price (with a correlation coefficient of 0.89).

and work as regular employees. The median labor force participation and regular employment rates for married women with children are 55.1% and 14.9%, respectively, which are notably lower than those for unmarried women (84.0% and 45.8%, respectively) and for married women without children (64.8% and 26.0%, respectively). The median part-time employment rate, on the other hand, is higher for married women with children (31.6%) than for unmarried women (17.3%) and married women without children (23.9%).

The spatial dispersion of the labor force participation rate of married women with children is larger than that of unmarried women or that of married women without children, as indicated by the wider range and greater standard deviation for married women with children. For the regular employment and part-time employment rates, differences in the spatial dispersion by marital status are relatively large but the differences by the presence of children among married women are small.

Table 2 reports the Global Moran's I statistics. The statistics are all significant at the 1% significance level, rejecting the null hypothesis of no spatial autocorrelation. In other words, commuting time and the labor force participation, regular employment, and part-time employment rates are not evenly distributed across municipalities within the metropolitan area. The Moran's I values are all positive and highly significant, indicating the existence of spatial clustering of high and low values.

As suggested by the Moran's I values and associated z scores, the magnitude of spatial clustering of the labor force participation, regular employment, and part-time employment rates is greater for married women with children than for unmarried women and married women without children. In addition to the first-order contiguity, we have experimented the following three spatial weights: (1) inverse distance; (2) inverse distance squared, and (3) fixed distance band (determined to include at least one municipality as a neighbor). The results above do not change by the use of the different spatial weights.

Figure 1 depicts commuting time for men and women and its hot spots (spatial clusters of high values) and cold spots (spatial clusters of low values) based on the Getis-Ord G_i^* statistics. For both men and women, considerable spatial disparities in commuting time exist. As the maps show, for men, most hot spots are located around the inner-suburban areas (within approximately 30 kilometers of the Tokyo ward area), suggesting that many men residing in the inner suburbs commute to the CBD, enduring a long commuting time. The cold spots of male commuting time are located around the core parts of the CBD and in the outer suburbs around the peripheries of the metropolitan area, suggesting that men residing in the outer suburbs work in the suburbs rather than commute to the central city. The spatial pattern of commuting time for women is similar to that for men but less conspicuous; for women, a lesser number of hot and cold spots exists. Most hot spots for women are located around the inner-suburban areas of Chiba, Kanagawa, and Tokyo prefectures.

Figure 2 shows the labor force participation rates of women and their hot and cold spots based on the Getis-Ord G_i^* statistics. It is visually apparent that the spatial pattern differs by marital status and the presence of children. In particular, striking differences exist in the spatial patterns between married women with and without children. For married women with children, the labor force participation rate exhibits a more distinctive spatial pattern. Most cold spots are located around the western parts of the Tokyo ward area and the inner suburbs, while most hot spots are located around the peripheries. For married women without children, on the other hand, the participation rate is more evenly distributed across municipalities, in accordance with their smaller and less significant Moran's I statistics (see Table 2). Comparing Figures 1 and 2, we see that for married women with children, many of the cold spots of the participation rate overlap with the hot spots of commuting time and vice versa (i.e., many of the hot spots of the participation rate overlap with the cold spots of commuting time). The visual spatial patterns suggest that the labor force participation of married women with children is more strongly related to commuting time than that of unmarried or married women without children.

Figure 3 portrays the hot and cold spots of the regular employment and part-time employment rates of women. For the regular employment rates, the spatial pattern differs remarkably by marital status and the presence of children, as in the case of the labor force participation rates. For married women with children, cold spots of the regular employment rate are mostly located in the inner-suburban areas, while hot spots are located in the outer suburbs; this spatial pattern is the reversed spatial pattern of commuting time (see Figure 1); that is, for these married women with children, many cold spots of the regular employment rate overlap with the hot spots of commuting time and vice versa. For unmarried women and married women without children, no clear spatial relationships exist. The spatial patterns of the part-time employment rates do not differ much by marital status and the presence of children, and they have no obvious spatial relationships with commuting time.

We examine correlations between the labor force participation, regular employment, and part-time employment rates and commuting time for men (Table 3). Here, male commuting time is used: since most men work, male commuting time is an accurate proxy that reflects the true cost of commuting.[3] The results support the visual impression of the spatial relationships from the maps (Figures 1-3). For married women with children, the labor force participation and regular-employment rates are highly and negatively correlated with male commuting time (with correlation coefficients of -0.71 and -0.78, respectively). For married women without children, the correlations are also negative but weaker, with correlation coefficients of -0.59 and -0.20, respectively. For unmarried women, the correlations are smaller, and the sign is positive (with correlation coefficients of 0.02 and 0.22, respectively). For the part-time employment rates, the correlations do not differ much by marital status

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[3] If a commute impedes participation (i.e., people choose not to work because of costly commuting), then latent commuting time for them does not show up in the data.

and the presence of children.

4.2 Regression results

Table 4 reports regression results for the labor force participation rates. The results for married men are presented for comparison.

The results of commuting time, the variable of our interest, indicate striking differences by marital status and the presence of children. For married men, unmarried women, and married women without children, commuting time is not significantly associated with the labor force participation rate. In contrast, for married women with children, an increase in commuting time is significantly associated with a decrease in the participation rate. The negative association between commuting time and labor force participation for married women with children (both under 6 years old and 6 years old or over) is greater for college graduates than for those with high school education or less, indicating that highly educated mothers are more sensitive to commuting time when participating in the labor market. For college-graduated married women with children (both under 6 years old and 6 years old or over), a one-minute increase in commuting time is associated with a 0.31 percentage point decrease in the labor force participation rate. Since the range of commuting time across municipalities is 46.2 minutes (see Table 1), the commuting time difference results in a 14.3 percentage point difference in the labor force participation rate for college-graduated married women with children. This is a large difference, given that the range of the participation rate for these women is 29.6 percent (the maximum of 40.2 percent minus the minimum of 10.6 percent). Besides the OLS estimates, Table 4 shows the estimates from the spatial lag and spatial error models when the LM statistics suggest the spatial models as preferred specifications. The sign and significance of the estimates on commuting time are consistent with those from the OLS models, and differences in the marginal effects of commuting time across the non-spatial and spatial models are small.[4]

The results of the control variables for women are as follows. Residential land price is negatively and mostly significantly associated with labor force participation. This result is similar to the finding by Black et al.'s (2014). a negative association between housing cost and labor force participation for married women. The coefficients of the unemployment rate are negative and significant for childless married women with high school education or less; for the other women, the coefficients are insignificant. The coefficients of the proportion of households with two or more children are positive and significant for unmarried women, but they are negative and significant for childless married women and college-graduated married women with children under 6 years old. The coefficients of the availability of childcare centers are positive and significant for married women with preschool-aged children and also for married women with high school education or less who have children aged 6 years or over.

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[4] The marginal effects for the spatial lag models are the total effects, as explained in Section 3.2.

Table 5 presents regression results for the regular employment rates. Results for the part-time employment rates are not presented since their associations with commuting time are mostly insignificant. As in the case of labor force participation, the results differ markedly by marital status and the presence of children. The coefficients of commuting time are insignificant for married women without children. The coefficients are positive and mostly significant for unmarried women, whereas they are negative and significant for married women with children. Among married women with children, the negative coefficients are greater in absolute values for college graduates than for those with high school education or less, as in the case of labor force participation. The association between commuting time and the regular employment rate is particularly strong for college-educated married women with children aged 6 years or over. For these women, a one-minute increase in commuting time is associated with a 0.32 percentage point decrease in the regular employment rate. Incorporating the range of commuting time (46.2 minutes) results in a 14.8 percentage point difference in the regular employment rate.

Table 5 also reports estimates from the spatial lag and spatial error models when the LM statistics suggest them as the preferred alternative to the non-spatial models. The spatial autoregressive coefficients (ρ and λ) are all significant. The sign and significance of our key variable, commuting time, are mostly the same across the non-spatial and spatial models, and differences in the marginal effects of commuting time are small.[5]

The results for the control variables are as follows. The coefficients of residential land price are negative and significant for married women with children. The coefficients of the unemployment rate are negative and mostly significant for unmarried women and married women with high school education or less. The coefficients of the proportion of households with two or more children are positive and mostly significant for unmarried women, whereas they are negative and mostly significant for married women. The availability of childcare centers is positively and significantly associated with regular employment for married women with children (except for college-educated women with preschool-aged children, for whom the coefficient is insignificant).

As robustness checks, we have estimated the models with three alternative specifications. First, we estimated the OLS models with the weighted least squares. Second, instead of using the first-order contiguity for the spatial weights matrix, we experimented the following spatial weights: (1) the inverse distance weights (with the power = 1 and 2) and (2) k-nearest neighbors (with a value of k = 4, 6, and 8). Finally, we estimated the non-spatial and spatial models for municipalities in which 10 percent or more male commuters travel to the Tokyo ward area to work. Appendices A1 and A2 contain

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[5] For unmarried women, the coefficient of commuting time is insignificant in the spatial lag model. This result may be due to the fact that the spatial lag coefficient (ρ) for S2SLS is 1.004, which exceeds the general upper bound of one. The marginal effect (total effect) is not computed for this spatial lag model. The Anselin-Kelejian test statistic (Anselin and Kelejian, 1997; Anselin, 2014), a diagnostic for spatial autocorrelation, is 15.35 with a p-value of 0.00, which indicates the presence of remaining spatial dependence. For the other spatial lag models in Tables 4 and 5, the Anselin-Kelejian test statistics are all insignificant, indicating no remaining spatial dependence.

the corresponding maps for male commuting time and the labor force participation and regular employment rates for women, respectively. The regression estimates for the labor force participation and regular employment rates are reported in Appendices B1 and B2, respectively. These different specifications and spatial weights did not change the result that the associations between commuting time and the labor force participation and regular employment rates are negative and significant for married women with children, while those associations are mostly insignificant for unmarried and married women without children.[6]

5. Conclusions

We use municipal-level data of the Tokyo metropolitan area to study the spatial patterns of female participation in the labor market and their associations with commuting time. We find that considerable intra-metropolitan disparities exist in the 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 based on the Getis-Ord G_i^* statistics reveal 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 the participation and regular employment rates, and these rates are negatively correlated with male commuting time. For married women with children, 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 commuting time.

The non-spatial and spatial regression results show that for married women with children, longer commuting time is significantly associated with lower labor force participation and regular employment rates, while for unmarried women and married women without children, the associations are mostly insignificant. These results are robust to different regression specifications and spatial weights. The findings support the view that labor market participation by mothers has salient sensitivity to commuting time. Since residential decisions are endogenous, the effect of commuting time on participation is not causal. Rather, the circumstances in the Tokyo metropolitan area induce households to decide location and labor market participation by both spouses simultaneously: the typical choices are (1) living in the suburbs, the husband commutes to the CBD, and the wife stays home or works locally, or (2) living close to the CBD and both spouses work at the CBD. Naturally, these choices result in sorting in residential location.

The regression results also show that among married women with children, the negative

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[6] In Appendix B2, the associations between commuting time and the regular employment rates become insignificant for married women with children under 6 years old, while the associations remain significant for married women with children aged 6 years and older. Therefore, we estimated the additional models for married women with children (of all ages); the results indicate that the association for these women is negative and significant.

associations between commuting time and the labor force participation or regular employment rates are greater for college graduates than for those with high school education or less. This result differs from those in Black et al. (2014), who find greater associations for high school graduates than for college graduates among married women.[7] These contradictory results may arise partly because our study is based on intra-metropolitan data, while the study by Black et al. (2014) is based on inter-metropolitan data. In the inter-metropolitan analysis, highly educated women are perhaps more likely to live and work in larger metropolitan areas that have longer commuting time. In our intra-metropolitan analysis of Tokyo, on the other hand, highly educated women are more likely to live and work closer to the CBD, with shorter commuting time.

Our findings suggest that for married women with children, intra-metropolitan disparities in commuting time play an important role in their participation in the labor market. The inner suburbs, which are commuting distance for men but farther away from the CBD, have high concentrations of lower rates of labor force participation and regular employment for married mothers and also have high concentrations of long male commuting time. Given that commuting time is not significantly associated with the labor force participation rate for married men (see Table 4), suburban living that entails long commuting for the husband intensifies the household division of labor, in which the husband commute to the CBD and the wife either stays home or works locally.

Perhaps this propensity is particularly conspicuous for Tokyo. Of 243 municipalities in the Tokyo metropolitan area, half have an average daily commuting time (for men) of over 100 minutes, and 13 municipalities have daily commuting time exceeding 120 minutes. Most of these municipalities are located in the inner suburbs. Among the 26 OECD countries, Japanese men do the least housework and related unpaid work; Japanese men on average spend 62 minutes on unpaid work while their spouses dedicate 299 minutes per day to unpaid work (OECD, 2016). It is conceivable that men who spend such lengthy time on commuting (often in heavily congested trains) are even less likely to do housework and perform childcare. It is also imaginable that women who bear most housework and childcare responsibilities are unable to cope with long commuting.

Among women with children in many countries, preferences for participation in the labor market are much higher than actual participation rates (Jaumotte, 2003; Gender Equality Bureau Cabinet Office of Japan, 2007). A national survey in Japan shows that among couples with children under 15 years old, the great majority (86%) of women who are not currently working actually wish to work (National Institute of Population and Social Security Research, 2016). Our results suggest that policies alleviating commuting constraints help women in dual-earner couples with children more actively participate in the labor market. Examples of such policies are improving accessibility to employment, reducing congestion, promoting flexible working hours, increasing housing supply

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

around employment centers, and encouraging male commitment to housework and childcare.

In recent years, the number of dual-earner couples in Japan has dramatically increased (The Japan Institute for Labour Policy and Training, 2016). Spatio-temporal analysis using data after 2010 is a task for further research. Geographic disparities in female participation are examined mostly at the national, metropolitan, and prefectural levels. Our research shows that within a metropolitan area, the levels of female participation also 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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Table 1. Summary statistics.

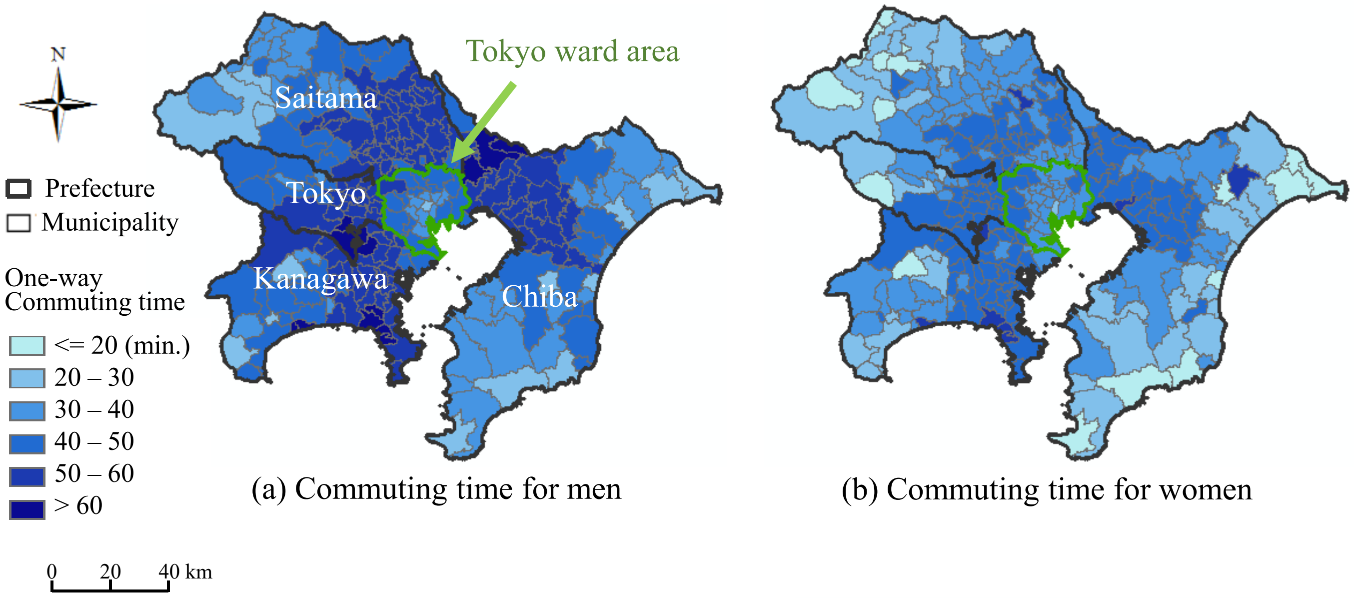
	Median	Mean	Std. Dev.	Min.	Max.
Commuting time (min.)					
Men	49.9	47.7	10.4	21.4	67.6
Women	38.8	37.0	9.2	11.7	59.7
Labor force participartion rate (%)					
Unmarried women	84.0	82.9	5.2	61.7	94.0
Married women					
No children	64.8	65.5	5.2	56.1	85.7
With children	55.1	57.4	8.7	40.5	79.6
Regular employment 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 : Men and women are 25-54 years old. The number of observations (municipalities) is 243 except that the number for married women without children is 242. Commuting time is the average one-way trave time to work.

Table 2. Global Moran's I statistics.

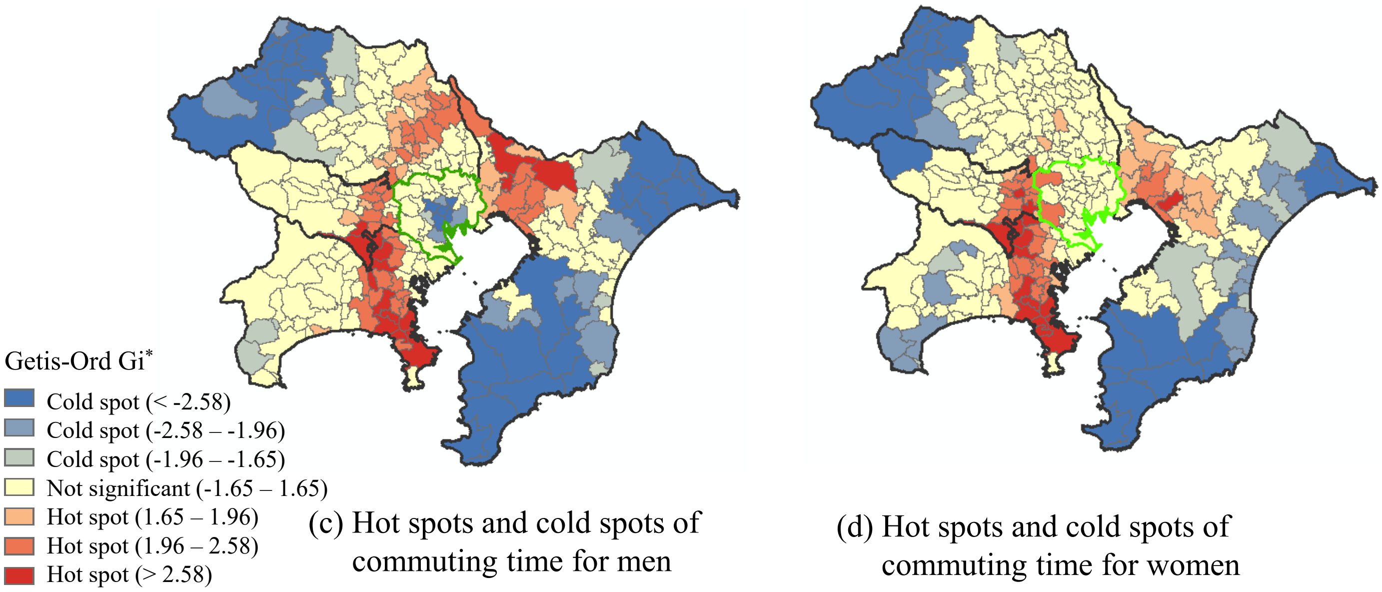
	Moran's I	z-score	p-value
Commuting time			
Men	0.66	16.22	0.00
Women	0.60	14.72	0.00
Labor force participartion rates			
Unmarried women	0.48	11.77	0.00
Married women			
No children	0.33	8.13	0.00
With children	0.76	18.77	0.00
Regular employment rates			
Unmarried women	0.31	7.72	0.00
Married women			
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 : Men and women are 25-54 years old. The number of observations (municipalities) is 243 except that the number for married women without children is 242. Commuting time is the average one-way travel time to work.



(a) Commuting time for men

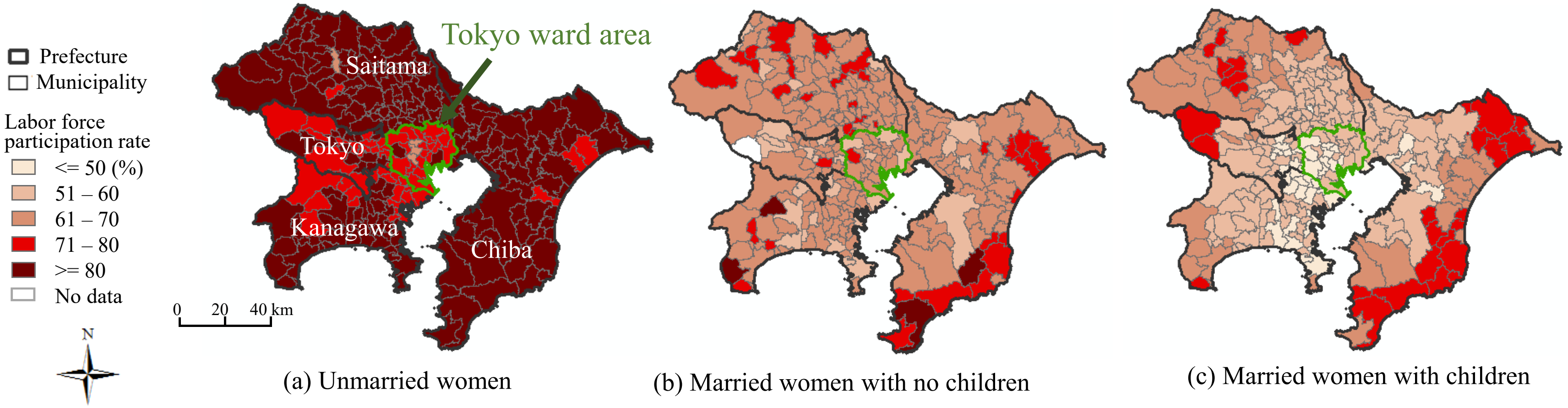
(b) Commuting time for women



(c) Hot spots and cold spots of commuting time for men

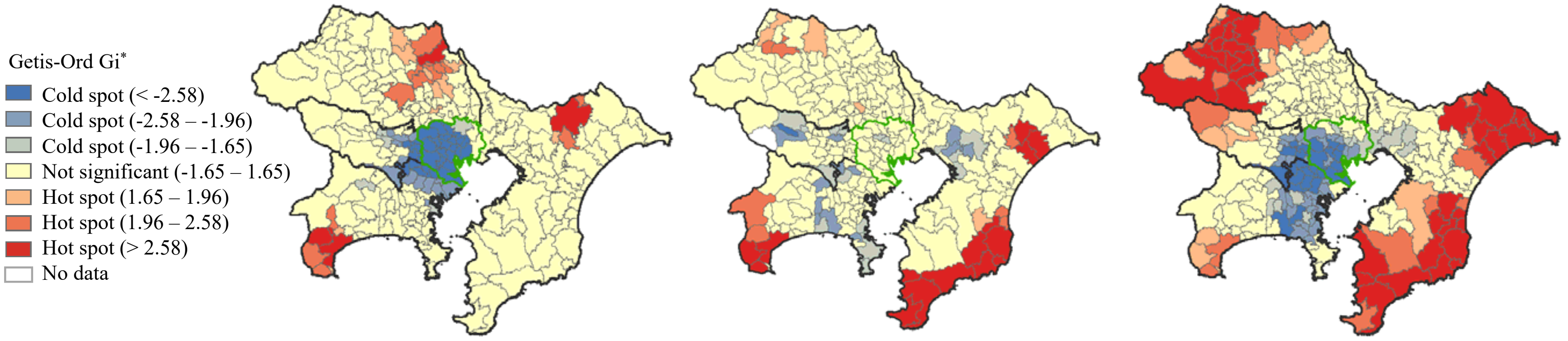
(d) Hot spots and cold spots of commuting time for women

Figure 1. Commuting time for men and women aged 25-54 years.



(a) Unmarried women (b) Married women with no children (c) Married women with children

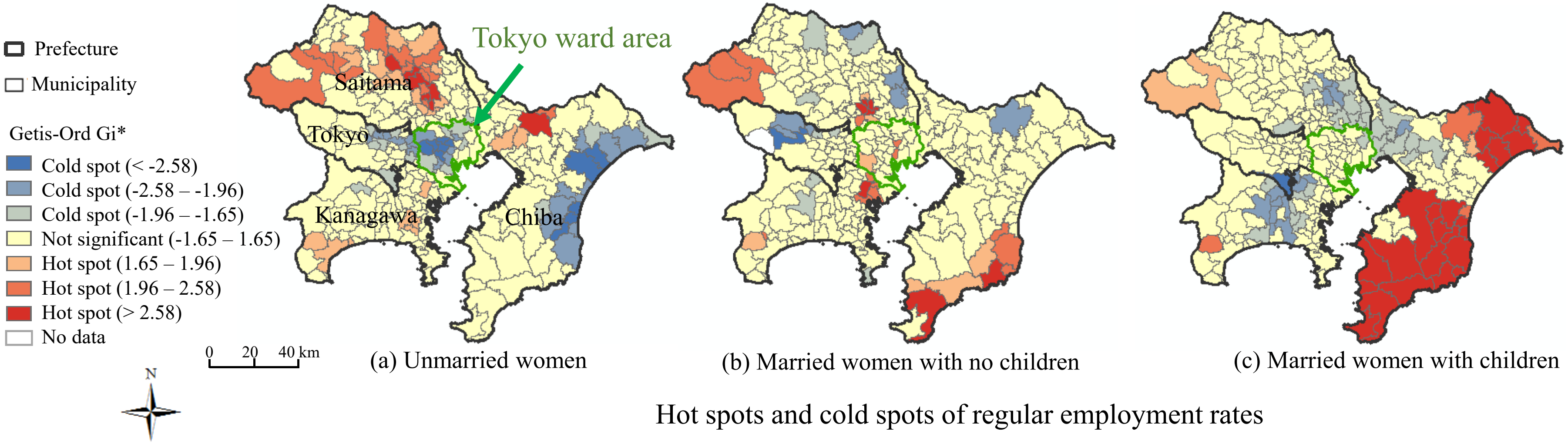
Labor force participation rates



(d) Unmarried women (e) Married women with no children (f) Married women with children

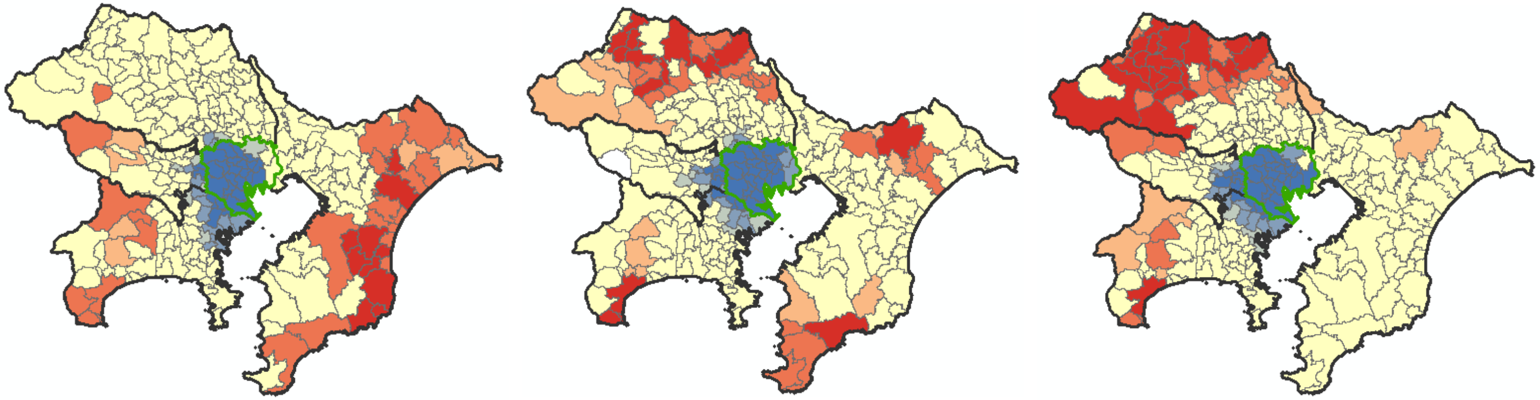
Hot spots and cold spots of labor force participation rates

Figure 2. Labor force participation rates for women aged 25-54 years.



(a) Unmarried women (b) Married women with no children (c) Married women with children

Hot spots and cold spots of regular employment rates



(d) Unmarried women (e) Married women with no children (f) Married women with children

Hot spots and cold spots of part-time employment rates

Figure 3. Regular and part-time employment rates for women aged 25-54 years.

Table 3. Getis-Ord Gi*: correlations with commuting time for men.

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	-0.22
Married women	
No children	-0.27
With children	-0.25

Note : Men and women are 25-54 years old. The number of observations (municipalities) is 243 except that the number is 242 for married women without children.

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
	OLS	Lag-S2SLS	Lag-ML	OLS	Lag-S2SLS	Lag-ML	OLS	Err-GMM	Err-ML	OLS	OLS	OLS	OLS	OLS
Commuting time	0.02	0.01	0.00	0.04	0.00	0.01	-0.08	-0.06	-0.06	0.00	-0.19 **	-0.31 **	-0.14 **	-0.31 **
	(0.020)	(0.017)	(0.017)	(0.03)	(0.04)	(0.03)	(0.05)	(0.05)	(0.05)	(0.07)	(0.05)	(0.07)	(0.03)	(0.06)
Log of residential land price	-1.98 **	-0.87 *	-0.81 **	-1.36 **	-0.04	-0.33	-2.77 **	-2.69 **	-2.67 **	-0.87	-2.66 **	-2.68 *	-1.63 **	-7.62 **
	(0.314)	(0.417)	(0.312)	(0.50)	(0.66)	(0.48)	(0.77)	(0.98)	(0.88)	(1.14)	(0.85)	(1.15)	(0.52)	(0.95)
Unemployment rate	0.35 *	0.32 **	0.32 **	0.35	0.38	0.37	-0.91 *	-0.78 *	-0.76 *	-0.06	-0.36	-0.36	0.09	0.51
	(0.144)	(0.115)	(0.125)	(0.23)	(0.28)	(0.21)	(0.35)	(0.38)	(0.36)	(0.53)	(0.40)	(0.54)	(0.25)	(0.45)
Households with two or more children	0.29 **	0.22 **	0.21 **	0.48 **	0.36 **	0.39 **	-0.54 **	-0.53 **	-0.53 **	-0.47 *	-0.02	-0.39 *	0.14	-0.23
	(0.052)	(0.047)	(0.047)	(0.08)	(0.11)	(0.08)	(0.13)	(0.15)	(0.14)	(0.19)	(0.14)	(0.19)	(0.09)	(0.16)
Availability of childcare centers	-0.01	0.00	0.00	-0.01	0.00	0.00	0.03	0.02	0.02	0.00	0.34 **	0.24 **	0.12 **	-0.04
	(0.012)	(0.011)	(0.010)	(0.02)	(0.02)	(0.02)	(0.04)	(0.05)	(0.05)	(0.07)	(0.05)	(0.07)	(0.03)	(0.05)
Spatial lag (*ρ)*		0.45 **	0.47 **		0.53 *	0.41 **								
		(0.114)	(0.067)		(0.21)	(0.07)								
λ								0.25 **	0.27 **					
								(0.08)	(0.09)					
Constant	109.08 **	55.57 **	52.96 **	85.83 **	30.73	42.63 **	114.89 **	112.33 **	111.98 **	94.52 **	70.12 **	94.30 **	87.24 **	174.35 **
	(4.705)	(14.524)	(8.800)	(7.527)	(21.94)	(9.88)	(11.78)	(14.62)	(13.34)	(17.56)	(13.13)	(17.88)	(8.08)	(14.70)
N	243	243	243	243	243	243	206	206	206	206	209	209	218	218
R^2	0.58	0.68	0.68	0.37	0.39	0.47	0.15	0.17	0.17	0.02	0.47	0.32	0.49	0.55

OLS	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*
LM spatial lag	69.71	0.00	30.78	0.00	2.87	0.09	2.55	0.11	2.62	0.11	0.04	0.84	2.66	0.10	1.13	0.29
LM spatial error	60.86	0.00	23.91	0.00	8.11	0.00	1.92	0.17	3.06	0.08	0.27	0.60	0.17	0.68	0.17	0.68
Robust LM spatial lag	10.11	0.00	7.13	0.01												
Robust LM spatial error	1.26	0.26	0.27	0.60												

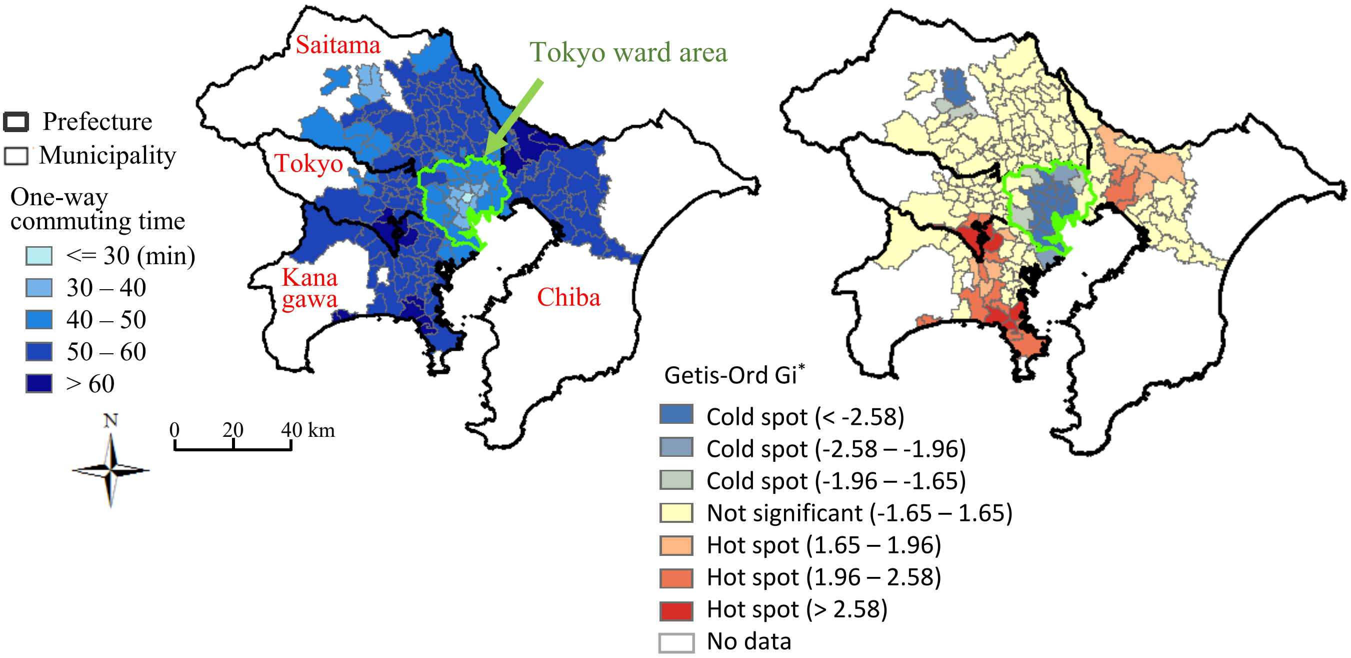
Note : Men and women are 25-54 years old. Standard errors are in parentheses. R^2 is adjusted R^2 for OLS and pseudo R^2 for spatial lag and spatial error models. *p* denotes p value.
Robust Lagrange Multiplier (LM) test statistics are reported when the LM test statistics for spatial lag and spatial error are both significant.
Municipalities with population less than 50 for each category of the presence of children and education are excluded from the sample.
**Significant at 1%; *Significant at 5%.

Table 5. Regression of regular employment.

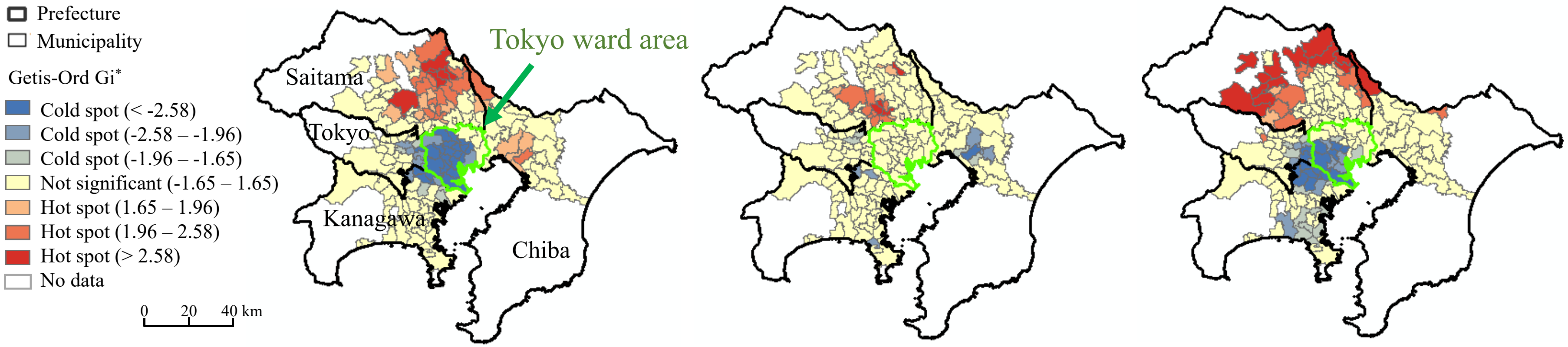
	Unmarried women			Married women									
				No children						With children under 6		With children, none under 6	
				HS or less			College			HS or less	College	HS or less	College
	OLS	Lag-S2SLS	Lag-ML	OLS	Err-GMM	Err-ML	OLS	Lag-S2SLS	Lag-ML	OLS	OLS	OLS	OLS
Commuting time	0.11 **	0.07	0.09 **	-0.07	-0.07	-0.06	-0.02	-0.18	-0.11	-0.12 **	-0.16 *	-0.09 **	-0.32 **
	(0.04)	(0.04)	(0.03)	(0.04)	(0.05)	(0.05)	(0.09)	(0.12)	(0.09)	(0.03)	(0.07)	(0.02)	(0.07)
Log of residential land price	-0.44	0.47	-0.07	-0.21	-0.31	-0.32	-0.75	-0.44	-0.58	-1.40 **	-2.31 *	-1.29 **	-6.79 **
	(0.55)	(0.72)	(0.51)	(0.66)	(0.71)	(0.74)	(1.43)	(1.58)	(1.36)	(0.51)	(1.12)	(0.35)	(1.09)
Unemployment rate	-0.97 **	-0.54	-0.80 **	-0.74 *	-0.70 *	-0.70 *	-1.06	-1.00	-1.03	-0.78 **	-0.43	-0.11	-0.34
	(0.26)	(0.28)	(0.24)	(0.30)	(0.33)	(0.31)	(0.66)	(0.89)	(0.63)	(0.24)	(0.53)	(0.16)	(0.51)
Households with two or more children	0.36 **	0.16	0.28 **	-0.26 *	-0.27 *	-0.27 *	-0.60 *	-0.81 **	-0.72 **	-0.31 **	-0.72 **	-0.23 **	-0.27
	(0.09)	(0.12)	(0.09)	(0.11)	(0.12)	(0.12)	(0.24)	(0.25)	(0.23)	(0.08)	(0.19)	(0.06)	(0.18)
Availability of childcare centers	0.03	0.07 *	0.05 *	0.01	0.01	0.01	0.02	-0.10	-0.05	0.06 *	0.04	0.14 **	0.19 **
	(0.02)	(0.04)	(0.02)	(0.04)	(0.04)	(0.04)	(0.08)	(0.12)	(0.08)	(0.03)	(0.07)	(0.02)	(0.06)
Spatial lag (ρ)		1.00 **	0.40 **					-0.60 **	-0.32 **				
		(0.23)	(0.08)					(0.21)	(0.10)				
λ					0.22 *	0.22 *							
					(0.10)	(0.09)							
Constant	44.15 **	-10.65	22.15 **	34.62 **	35.41 **	35.49 **	69.25 **	105.34 **	88.69 **	41.64 **	76.89 **	33.66 **	122.50 **
	(8.32)	(17.61)	(8.23)	(10.10)	(10.59)	(11.21)	(22.02)	(24.78)	(21.44)	(7.84)	(17.34)	(5.33)	(16.73)
N	243	243	243	206	206	206	206	206	206	209	209	218	218
R^2	0.17	0.29	0.20	0.10	0.12	0.12	0.05	0.15	0.14	0.25	0.14	0.59	0.54

OLS	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*
LM spatial lag	30.26	0.00	2.30	0.13	10.64	0.00	3.06	0.08	0.00	1.00	2.58	0.11	0.01	0.94
LM spatial error	25.18	0.00	4.29	0.04	5.95	0.01	2.59	0.11	0.18	0.67	0.31	0.58	1.39	0.24
Robust LM spatial lag	5.45	0.02			6.87	0.01								
Robust LM spatial error	0.38	0.54			2.18	0.14								

Note : Women are 25-54 years old. Standard errors are in parentheses. R^2 is adjusted R^2 for OLS and pseudo R^2 for spatial lag and spatial error models. *p* denotes p value.
Robust Lagrange Multiplier (LM) test statistics are reported when the LM test statistics for spatial lag and spatial error are both significant.
Municipalities with population less than 50 for each category of the presence of children and education are excluded from the sample.
**Significant at 1%; *Significant at 5%.

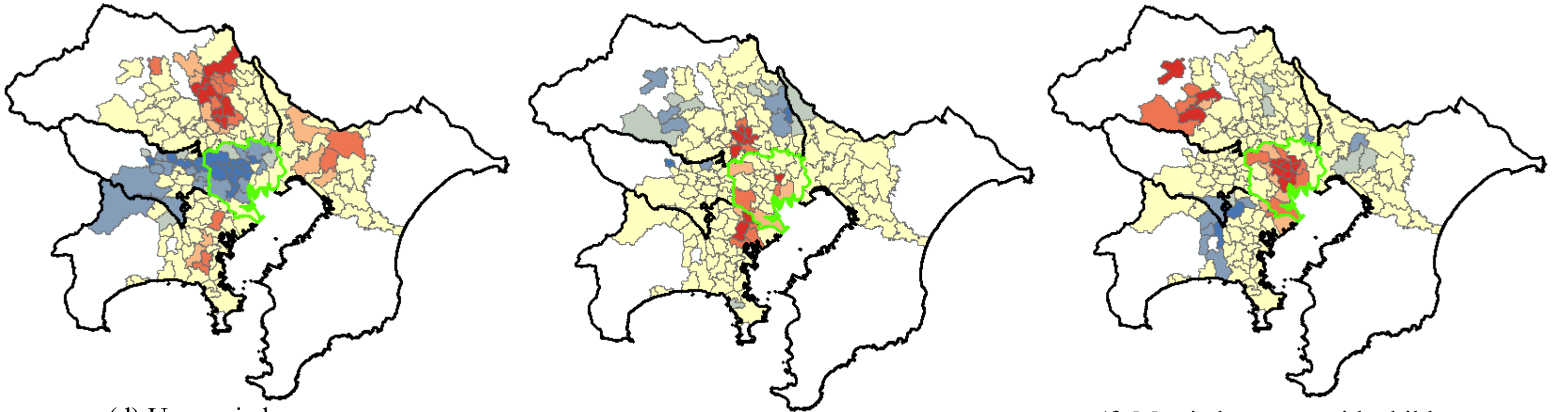


Appendix A1. Commuting time for men aged 25-54 years for municipalities in which 10 percent or more male commuters travel to the Tokyo ward area to work.



(a) Unmarried women (b) Married women with no children (c) Married women with children

Hot spots and cold spots of labor force participation rates



(d) Unmarried women (e) Married women with no children (f) Married women with children

Hot spots and cold spots of regular employment rates

Appendix A2. Labor force participation and regular employment rates for women aged 25-54 years for municipalities in which 10 percent or more male commuters travel to the Tokyo ward area to work.

Appendix B1. Regression of labor force participation for municipalities in which 10% or more male commuters travel to the Tokyo ward area to work.

	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
	OLS	Err-GMM	Err-ML	OLS	Err-GMM	Err-ML	OLS	OLS	OLS	OLS	Lag-S2SLS	Lag-ML	OLS	OLS
Commuting time	0.03	0.04	0.04	0.02	0.05	0.05	-0.05	-0.10	-0.16 *	-0.32 **	-0.41 **	-0.38 **	-0.20 **	-0.21 **
	(0.03)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.07)	(0.08)	(0.07)	(0.08)	(0.08)	(0.08)	(0.05)	(0.08)
Log of residential land price	-1.98 **	-2.34 **	-2.36 **	-1.00	-1.04	-1.02	-1.11	0.04	-2.18	-2.70	-2.13	-2.34	-1.39	-5.97 **
	(0.63)	(0.65)	(0.68)	(0.89)	(1.1)	(0.97)	(1.33)	(1.52)	(1.42)	(1.65)	(1.86)	(1.61)	(0.93)	(1.48)
Unemployment rate	0.44	0.15	0.12	0.41	0.26	0.25	-0.53	0.08	0.36	0.35	0.49	0.44	0.23	0.57
	(0.24)	(0.24)	(0.23)	(0.34)	(0.4)	(0.34)	(0.5)	(0.55)	(0.53)	(0.61)	(0.7)	(0.59)	(0.35)	(0.56)
Households with two or more children	0.35 **	0.29 **	0.28 **	0.66 **	0.62 **	0.61 **	-0.42 *	-0.22	-0.01	-0.45 *	-0.49 *	-0.48 *	0.26 *	-0.14
	(0.08)	(0.09)	(0.08)	(0.12)	(0.13)	(0.12)	(0.18)	(0.2)	(0.19)	(0.22)	(0.24)	(0.21)	(0.13)	(0.2)
Availability of childcare centers	-0.04	-0.01	0.00	-0.06	0.00	0.00	-0.07	0.02	0.40 **	0.25 **	0.22 *	0.24 **	0.14 **	0.01
	(0.03)	(0.03)	(0.03)	(0.05)	(0.04)	(0.05)	(0.07)	(0.08)	(0.07)	(0.09)	(0.09)	(0.08)	(0.05)	(0.08)
Spatial lag (*ρ*)											-0.31 *	-0.20 *		
											(0.15)	(0.09)		
λ		0.47 **	0.48 **		0.41 **	0.43 **								
		(0.09)	(0.09)		(0.1)	(0.09)								
Constant	107.65 **	113.83 **	114.30 **	80.07 **	79.57 **	79.06 **	90.98 **	83.43 **	57.23 *	92.04 **	103.54 **	99.36 **	83.93 **	146.04 **
	(9.97)	(9.87)	(10.44)	(14.23)	(16.47)	(15.02)	(21.13)	(24.08)	(22.51)	(26.29)	(25.17)	(25.38)	(14.78)	(23.53)
N	163	163	163	163	163	163	163	161	163	162	162	162	163	163
R^2	0.59	0.60	0.59	0.52	0.53	0.53	0.05	0.03	0.28	0.27	0.32	0.32	0.26	0.26

OLS	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*
LM spatial lag	0.66	0.42	0.79	0.37	0.02	0.88	1.27	0.26	3.48	0.06	4.19	0.04	0.39	0.53	0.16	0.69
LM spatial error	21.69	0.00	14.88	0.00	0.39	0.53	0.43	0.51	2.50	0.11	1.10	0.29	0.08	0.78	2.27	0.13

Note : Men and women are 25-54 years old. Standard errors are in parentheses. R^2 is adjusted R^2 for OLS and pseudo R^2 for spatial lag and spatial error models. *p* denotes p value.
Municipalities with population less than 50 are excluded. Robust Lagrange Multiplier (LM) test statistics are not reported since none of the LM test statistics for spatial lag and spatial error are both significant.
**Significant at 1%; *Significant at 5%.

Appendix B2. Regression of regular employment for municipalities in which 10% or more male commuters travel to the Tokyo ward area to work.

	Unmarried women			Married women											
				No children				With children				With children under 6		With children, none under 6	
				HS or less			College	HS or less	College			HS or less	College	HS or less	College
	OLS	Err-GMM	Err-ML	OLS	Lag-S2SLS	Lag-ML	OLS	OLS	OLS	Err-GMM	Err-ML	OLS	OLS	OLS	OLS
Commuting time	0.01	0.05	0.06	-0.01	-0.02	-0.02	-0.23 *	-0.10 **	-0.22 **	-0.27 **	-0.27 **	-0.05	-0.14	-0.12 **	-0.22 **
	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)	(0.09)	(0.03)	(0.05)	(0.04)	(0.04)	(0.04)	(0.08)	(0.03)	(0.06)
Log of residential land price	-2.52 **	-2.29	-2.23 *	0.84	-0.96	0.10	2.82	-0.22	-3.44 **	-3.39 **	-3.37 **	0.76	-2.12	-0.50	-3.38 **
	(0.92)	(1.25)	(0.98)	(1.1)	(1.18)	(1.08)	(1.83)	(0.49)	(1.01)	(1.08)	(0.83)	(0.8)	(1.53)	(0.56)	(1.18)
Unemployment rate	-1.03 **	-1.00 *	-0.99 **	-0.54	-0.53	-0.54	-0.11	-0.08	-0.06	-0.16	-0.17	-0.28	-0.59	0.02	0.73
	(0.35)	(0.41)	(0.36)	(0.42)	(0.44)	(0.4)	(0.66)	(0.18)	(0.38)	(0.31)	(0.32)	(0.3)	(0.56)	(0.21)	(0.45)
Households with two or more children	0.19	0.21	0.21	-0.29 *	-0.32 *	-0.30 *	-0.12	-0.13	-0.50 **	-0.47 **	-0.47 **	-0.10	-0.66 **	-0.13	-0.21
	(0.12)	(0.15)	(0.12)	(0.15)	(0.16)	(0.14)	(0.24)	(0.07)	(0.14)	(0.15)	(0.12)	(0.11)	(0.21)	(0.08)	(0.16)
Availability of childcare centers	-0.10 *	-0.05	-0.04	-0.12 *	-0.08	-0.10	-0.16	0.11 **	-0.02	-0.02	-0.02	0.10 *	0.06	0.11 **	-0.04
	(0.05)	(0.04)	(0.05)	(0.06)	(0.05)	(0.06)	(0.09)	(0.03)	(0.05)	(0.05)	(0.04)	(0.04)	(0.08)	(0.03)	(0.06)
Spatial lag (*ρ)*					0.60 **	0.25 *									
					(0.17)	(0.1)									
λ	With childre	0.33 **	0.31 **							-0.40 **	-0.40 **				
		(0.08)	(0.1)							(0.12)	(0.12)				
Constant	80.51 **	74.24 **	72.64 **	21.15	31.07	25.24	26.95	19.06 *	86.60 **	88.45 **	88.47 **	4.48	73.12 **	23.85 **	73.80 **
	(14.69)	(18.6)	(15.44)	(17.56)	(17.66)	(16.84)	(29.01)	(7.81)	(16.11)	(17.45)	(13.19)	(12.72)	(24.41)	(8.87)	(18.81)
N	163	163	163	163	163	163	161	163	163	163	163	163	162	163	163
R^2	0.31	0.33	0.32	0.16	0.23	0.22	0.14	0.36	0.19	0.22	0.21	0.16	0.15	0.32	0.18

OLS	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*	Value	*p*
LM spatial lag	1.86	0.17	4.98	0.03	0.98	0.32	1.50	0.22	0.08	0.78	0.09	0.76	0.08	0.78	1.06	0.30	0.04	0.85
LM spatial error	7.68	0.01	2.36	0.12	0.66	0.42	0.48	0.49	6.36	0.01	0.00	0.96	1.34	0.25	0.50	0.48	1.12	0.29

Note : Women are 25-54 years old. Standard errors are in parentheses. R^2 is adjusted R^2 for OLS and pseudo R^2 for spatial lag and spatial error models. *p* denotes p value.
Municipalities with population less than 50 are excluded. Robust Lagrange Multiplier (LM) test statistics are not reported since none of the LM test statistics for spatial lag and spatial error are both significant.
**Significant at 1%; *Significant at 5%.