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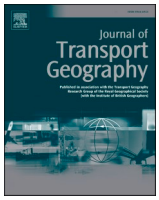

# Interaction effects of socioeconomic factors on long-distance commuting after disentangling residential self-selection: An empirical study in Xiamen, China

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ABSTRACT

The adjustment of urban spatial structure in the process of urbanization and suburbanization leads to the separation of work and residence, which further leads to long-distance commuting. While there has been a lot of research on long-distance commuting in Western countries, the relevant studies in China are not enough. In the Chinese context, some factors deserve special attention, namely the *hukou* system and occupation. However, few studies have focused on the individual and interaction effects of these two factors on long-distance commuting. This paper explores the commuting behavior of different socioeconomic groups in Xiamen, China. Heckman's sample selection model was applied to data from the 2015 Xiamen household travel survey to separate the effect of socioeconomic factors and that of residential selection. Results show that the continued suburbanization of the industry attracted substantial numbers of blue-collar workers to live in the outer districts (Haicang, Jimei, Tong'an, and Xiang'an), and thus blue-collar workers are less likely than pink- and white-collar workers to be long-distance commuters in the outer districts. Among residents of the outer district, pink-collar migrants and white-collar migrants are more likely to be long-distance commuters than their local counterparts, while blue-collar migrants (a coefficient of −0.153) are less likely to be long-distance commuters than blue-collar locals (a coefficient of −0.046). For people who live in the inner districts, blue-collar locals (a coefficient of 0.256) are more likely to be long-distance commuters than blue-collar migrants (a coefficient of −0.029). These results have practical significance for providing alternative housing for migrants in urban renewal.

## 1. Introduction

In the process of urbanization and suburbanization, the adjustment of urban spatial structure has resulted in the separation of jobs and housing. Coupled with the development of transportation, the average commuting distance and time have increased to a certain extent. For instance, daily one-way commutes in the United States increased from 25 min to 27.6 min from 2006 to 2019 (Burd et al., 2021), while in the United Kingdom it increased from 17.4 min to 21.6 min from the 2000s to the 2010s (Giménez-Nadal et al., 2022). It is well known that increasing commuting time can cause environmental and social problems. On the one hand, the increase in travel distance and urban traffic volume leads to an increase in carbon emissions. In Europe, daily commuting generates around 25% of total CO2 emissions (Giménez-Nadal et al., 2022). On the other hand, a longer commuting time is associated with certain negative outcomes, such as lower subjective well-being for women (Kahneman and Krueger, 2006), increased stress (Gottholmseder et al., 2008), and reduced leisure time (Giménez-Nadal et al., 2018). In some developing countries, disadvantaged groups have longer commutes, which undoubtedly exacerbates social inequality

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(Bautista-Hernández, 2020; Zhao, 2015). The abovementioned issues are particularly important in China, which has become the world's largest carbon emissions emitter, and where disadvantaged groups tend to be more likely than advantaged groups to use public transportation to extend commutes (Li et al., 2021). To solve these issues and provide planning guidance, it is critical to study the influential factors for long-distance commuting in China.

The definition of long-distance commuting varies from country to country, mostly based on commuting distance or time. In terms of commuting distance, studies in Europe and the United States took 30-100 km (Andersson et al., 2018; Sandow and Westin, 2010) and 80-160 km (Lapham, 1995; Sivaraman, 2015) as the threshold of long-distance commuting, respectively. Regarding commuting time, 30–45 min is generally considered to be the threshold of commuting time that travelers can bear (Clark et al., 2003). Thus, previous studies used 40–45 min as the threshold for long-distance commuting (Clark et al., 2003; Sandow and Westin, 2010). For instance, Cassel et al. (2013) defined long-distance commuting as "a journey to work taking at least 40 min". Since individuals are more sensitive to commuting time than commuting distance (Öhman and Lindgren, 2003), we chose >45 min as an indicator of long-distance commuting, which is the turning point for changes in behavioral preferences (Huang et al., 2018; Stenpaß and Kley, 2020).

While there has been a lot of research on long-distance commuting in Western countries, the relevant studies in China are not enough (Mallett, 2001; Mitra and Saphores, 2019; Öhman and Lindgren, 2003; Stenpaß and Kley, 2020). Most Chinese studies have focused on commuting rather than specifically on long-distance commuting (Hu et al., 2018; Zhu et al., 2017). However, since the determinants of long-distance commuting differ from those of short-distance commuting, the results of the commuting studies may not apply to the study of long-distance commuting. Studies in Western countries have proven that socioeconomic factors such as gender, age, education level, income, children, occupation, and family structure have an impact on long-distance commuting (Andersson et al., 2018; Sandow, 2014). In the Chinese context, there is an additional factor that deserves special attention, namely the *hukou* system. The *hukou* system (i.e., the household registration system) is a population management system based on households, through which the legality of natural persons living and working in a certain place can be determined (Zhao and Howden-Chapman, 2010). The *hukou* system imposes certain restrictions on the housing market, leading to differences in housing choices between locals and migrants (Li et al., 2021). For instance, according to policy restrictions, unmarried migrants are not allowed to buy a house in Shanghai, while other cities have stricter purchase restrictions on migrant workers. In addition, migrants are excluded from the cheaper local social housing system (Zhao and Howden-Chapman, 2010). Therefore, differences exist in spatial distribution and commuting patterns between migrants and locals (Li et al., 2022). An equally important factor in the Chinese context is occupation, which is related to the policy of "suppress the second industry and develop the third industry" started in the 1990s. This policy not only accelerated economic restructuring, but also stimulated the relocation of many secondary industries from urban centers to suburbs (Li et al., 2021), which eventually resulted in reverse commuting (i.e. commuting flow from the inner cities to suburbs). However, few previous studies have focused on these two factors' individual and interaction effects on long-distance commuting.

Moreover, residential self-selection bias has rarely been addressed in the field of long-distance commuting. Residential self-selection means that individuals may choose where they live based on their lifestyle and personal preferences or constraints (Cao, 2009). As a result, those who cannot afford high housing prices in the city center may choose to live in cheaper suburbs. While this bias may influence the relationship between socioeconomic factors and long commutes, there has been little discussion on the specific topic of long commutes. The study of Mitra and Saphores (2019) is an exception, confirming the effect of residential self-selection in their study of long-distance commuting. Therefore, additional attention should be paid to the effect of self-selection on long-distance commuting.

To fill this gap, this research conducts an exploratory analysis of the extent to which socioeconomic factors, especially occupation and *hukou*, determine long-distance commuting when controlling for residence selection bias. Knowledge of long-distance commuting in Xiamen, China, can help policymakers formulate more affordable housing policies and rational spatial strategies. Like other coastal cities, Xiamen has attracted an influx of capital and migrants since 1978, and has experienced its second industrial suburbanization since the late 1990s. Therefore, the research on Xiamen has implications for many other Chinese coastal cities. With this intention, a two-step model was conducted by examining determinants of residential choice in the first step and determinants of long-distance commuting in the second step.

Following the introduction, the rest of the paper is structured as follows. In Section 2, we present a review of the existing literature. In Section 3, we briefly introduce the study area and the two-step model. Section 4 is dedicated to the results of the model outcomes for Xiamen. The conclusions and findings are presented in Section 5.

## 2. Literature review

Long-distance commuting is influenced by a variety of factors, including socioeconomic and built-environmental factors. In this section, research on long-distance commuting in different contexts in different regions of the world was reviewed. Then, a factor unique to China, the hukou system, was introduced.

Data from several studies suggest that long-distance commuting decreases with increasing age (McQuaid and Chen, 2012; M. van Ham et al., 2001). Amcoff (2009) found in Sweden that young adults (15–24 years old) had the longest average commuting distance. Others argue that the influence of age is less pronounced (Limtanakool et al., 2006; Van Ham and Hooimeijer, 2009). In addition, some found that the relationship between age and long-distance commuting is non-linear, first increasing and then decreasing with age (Hu et al., 2018; Sandow and Westin, 2010).

In addition, other individual and household attribute also determine long-distance commuting. A common finding is that men commute longer distances than women (Dargay and Clark, 2012; Guttman et al., 2018; Hu et al., 2018), as mothers play a greater role in childcare and housework, leaving less time for commuting (Turner and Niemeier, 1997). In general, household size is negatively related to long-distance commuting. Dargay and Clark (2012) found that the more complex the family composition, the shorter the commuting distance. In contrast, in Shanghai, China, Hu et al. (2018) found that it to be positively related to long-distance commuting.

Additionally, having a university degree increases the probability of long-distance commuting in Sweden, since highly qualified jobs are more spatially concentrated, resulting in longer commutes to those jobs (Cassel et al., 2013).

Another finding is that car ownership and housing ownership impact whether they engage in long-distance commuting. Generally, individuals with a car are more likely to be long-distance commuters than those without a car (Champion et al., 2009; Limtanakool et al., 2006).

Homeowners are less likely to relocate than renters due to high transaction costs (Dieleman, 2001; Helderman et al., 2004). Consequently, homeownership is positively related to long-distance commuting.

Numerous studies have examined the relationship between occupational attributes and long-distance commuting (Aguiléra and Proulhac, 2015; McQuaid and Chen, 2012). In the case of the United States, O'Kelly and Lee (2005) found that blue-collar workers—who perform manual labor—commute longer distances than white-collar workers—who engaged in professional, managerial, or administrative work. In addition, they found that pink-collar workers—who perform service-related work—had shorter commutes. In the UK case, white-collar

workers occupy the highest percentage of long-distance commuters, while pink-collar workers occupy the lowest percentage (McQuaid and Chen, 2012).

Some studies have focused on the impact of geographical and built environmental factors on long-distance commuting. Mitra and Saphores (2019) found that the job-housing ratio at residence negatively affects long-distance commuting in California. In addition, Rowe and Bell (2020) found that population density and job accessibility negatively affect long-distance commuting in Chile.

Moreover, recent studies also show that commuting behavior can be explained by the self-selection hypothesis. Households may not only align their commuting behavior to the constraints of their residential location but also can self-select their residential locations according to their travel-related attitudes (Bohte et al., 2009). For instance, individuals who prefer to use a car could choose environmentally friendly locations as their residential areas (Zhao, 2015), while individuals who could not afford private cars may choose places close to their work so that they can avoid long-distance commuting. Cao (2009) found that residential self-selection has a significant impact on travel behavior. Evidence suggests that residential self-selection issues may overestimate the relationship between the built environment and travel behavior (Cao, 2009; Tran et al., 2016; Zhou and Kockelman, 2008). To control residential self-selection, various modeling approaches have been proposed, including joint discrete choice models, structural equations models, statistical control models, propensity score-based techniques, and sample selection models (Cao, 2009; van Herick and Mokhtarian, 2020). However, these studies dealing with the effects of self-selection have been limited to the general area of travel behavior, not long-distance commuting.

Long-distance commuting is inherently a matter of excessive separation of living and work. Different industries have different spatial distribution patterns, and corresponding workers also have certain distribution patterns. For example, many developed countries and some developing cities have experienced the displacement of the secondary industry from urban centers to suburbs. In the United States, the spatial mismatch between the inner-city African Americans and the suburban blue-collar jobs in the 1970s was the root cause of their becoming long-distance commuters. However, such differences in job types, especially those with distinct spatial distribution patterns, are often ignored by long-distance commuting studies. Therefore, this study analyzes the differences in long-distance travel among blue-, pink-, and white-collar workers, which enables us to better understand the causes of long-distance commuting.

As mentioned in the introduction, *hukou* is also an important factor in the emergence of different residential distribution patterns in the Chinese context. After market-oriented transformations and related institutional changes, large numbers of migrants have flocked to the cities, mainly engaging in labor-intensive industries and living in urban villages, which are also known as "villages in the city" (ViCs)[1] (Lin and Gaubatz, 2017). Unlike migrants who cluster in specific areas, locals are spread over larger urban spaces, and these spatial differences will lead to inconsistent commuting patterns. Meanwhile, there is a potential interaction between *hukou* and occupation. A detailed study of these interactions among different socioeconomic groups would provide a scientific basis for better spatial planning.

## 3. Methodology and data

### 3.1. Study area and data source

Xiamen is a large city in Fujian Province, China, with a permanent population of over 4 million in 2019. Xiamen is also a tourist city known for its charming seascape. The urban built-up area has spread from the southwestern coastal area on the island of Xiamen (inner districts, namely Siming and Huli), to other districts (outer districts, namely Haicang, Jimei, Tong'an, and Xiang'an). The inner-district population is basically saturated, and most of the new population is absorbed by the outer districts. Between 2016 and 2020, the population growth in the inner districts was only 40,000, while that in the outer districts reached nearly 500,000.

Before the 1980s, the population of Xiamen was mainly concentrated in the southwestern coastal area of Xiamen Island. In 1980, Xiamen became one of China's original four special economic zones (SEZs), covering an area of 2.5 $km^2$ in the current Huli District.[2] In 1984, the Xiamen SEZ was extended to the entire inner districts, now covering 131 $km^2$. Subsequently, the State Council authorized three Taiwanese investment zones that would enjoy the same policy of Xiamen SEZ in Haicang (in 1989), Jimei (in 1989), and Xinglin (in 1992). These three Taiwanese investment zones have played a prominent role in the development of Jimei and Haicang, promoting the transformation of the city from the "island city" in the 1980s to the "island–gulf city" in the 1990s (Cao and Liu, 2007). The 1990s was also a period of rapid development in the Huli District. The Xiangyu bonded area (1992) and Xiamen Torch Hi-Tech Industrial Development Zone (1991) facilitated the development of the modern logistics industry and high-tech industry that interact with international logistics and regional logistics in the Huli District. In the 2000s, the industrial zone (IZ) on the mainland of Xiamen developed rapidly. Since then, the secondary industry in the inner districts has gradually moved to the outer districts, which accounted for two-thirds of the city's industrial output in 2014.

The data of this study were obtained from the 2015 Xiamen household travel survey by the Xiamen urban planning and design research institute. A total of 40,201 households were surveyed, including 10,290 households using personal digital assistants[3] and 29,911 households using questionnaires. The survey included 120,603 individual travel surveys, accounting for 3% of the total population of Xiamen. This survey is based on the population size, household size, gender distribution, and age distribution information of each administrative district in the "Sixth census of Xiamen City in 2010". The survey covers household characteristics, individual characteristics, travel times, travel purpose, origin and destination, travel mode, travel time, travel distance, etc. Data on 36,270 commutes were retained after excluding missing data and data unrelated to commuting.

The road network of Xiamen is shown in Fig. 1. Four cross-sea bridges and two tunnels have been built to connect the inner districts with the outer districts. Regarding public transportation, Xiamen opened 408 ordinary bus lines in 2020, including 8 bus rapid transit (BRT) lines. Xiamen's first BRT opened on August 31, 2008, while Xiamen's first metro line opened on Dec 31, 2017.

### 3.2. Method

Heckman's selection model is frequently used in travel behavior research to separate the effect of the built environment from that of self-selection (Cao et al., 2009; Hong et al., 2014). The basic idea behind this

[1] A ViC was originally a rural settlement that in the process of continuous urbanization was encapsulated by a growing city and now forms an urban neighborhood of that city. ViCs are usually "managed" by the original villagers (Lin et al., 2014).

[2] Huli District was founded in November 1987 and is the place of origin of the Xiamen SEZ.

[3] A personal digital assistant is a variety of mobile device that provides computing, information storage, and retrieval capabilities for individuals or businesses.

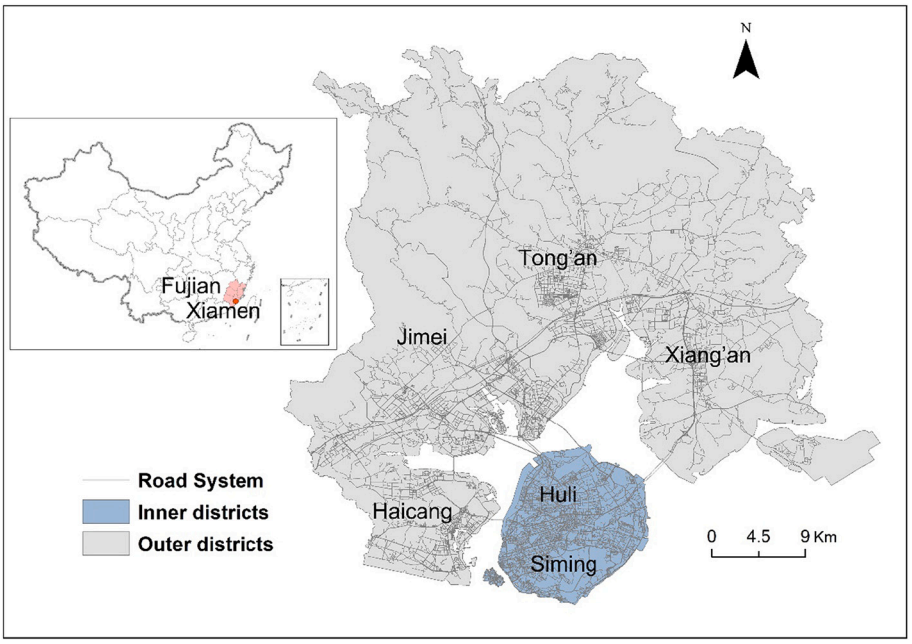


**Fig. 1.** Xiamen city in China: location and administrative divisions.

sample selection model is to model the prior selection into a binary state (inner vs. outer districts) in the first step, and then model the outcome of long-distance commuting as a conditional on that prior selection in the second step (Cao et al., 2009). Since the second-step dependent variable (whether to be a long-distance commuter) is binary in our model, we conducted a Heckman probit model, which enables the estimation of binary-dependent outcome variables.

In the first step, we separately analyzed the residential choices in the outer districts (outside Xiamen Island) and the inner districts (Xiamen Island). Although the outer districts are not suburbs in the strict sense of the word, they do have many suburban features: separated areas with some distance from the central inner-city areas; in the process of sub-urbanization, commercial, financial, and other tertiary industries are clustered in Xiamen Island (inner districts), while labor-intensive industries are moving to the outer districts.

In the second step, for individuals living in the outer districts (or living in the inner districts), we analyzed whether they travel for long distance commuting.

The selection equation (first stage) can be written as:

$$Y_i^{'} = \gamma Z_i + \mu_{1i} > 0 \quad (1)$$

where $Y_i^{'} = 1$ if $(\gamma Z_i + \mu_{1i}) \rangle 0$, and $Y_i^{'} = 0$ if $(\gamma Z_i + \mu_{1i}) \leq 0$; $Y_i^{'}$ represents the binary result of living in the inner or outer districts; $Z_i$ stands for explanatory variables of living in the outer districts (or living in the inner districts), mainly including socioeconomic variables (see Table 1); $\gamma$ denotes corresponding coefficients of explanatory variables; $\mu_{1i}$ is the error term of the selection equation.

The outcome model (second stage) can then be structured as follows:

$$Y_i = \beta X_i + \mu_{2i} \quad (2)$$

where $\mu_{2i} \sim N(0, \sigma^2)$ and $\mu_{1i} \sim N(0,1)$ & $\text{cov}(\mu_{2i}, \mu_{1i}) = 0$; $Y_i = 1$ if $(\beta X_i + \mu_{2i}) > 0$, and $Y_i = 0$ if $\beta X_i + \mu_{2i} \leq 0$; $Y_i$ is the binary outcome representing whether to be a long-distance commuter, observed only when $Y_i^{'} = 1$; $X_i$ stands for explanatory variables of long-distance commuting, mainly including locational and socioeconomic variables (see Table 1); $\beta$ denotes corresponding coefficients of explanatory variables; $\mu_{2i}$ is the error term.

### 3.3. Variables

#### 3.3.1. First stage variables (outer districts vs. inner districts)

The dependent variable in the first stage indicates whether the residents live in the outer or inner districts. Regarding independent variables, a variety of evidence supports socioeconomic characteristics such as age, household income, household characteristics, education level, and occupation type determine whether residents live in the suburbs (Acheampong, 2018). Unfortunately, since our dataset does not include income data, income was not selected as an independent variable. In the Heckman probit selection model, the selection model (first stage) should have at least one variable that is not in the outcome model; otherwise, there is no structural explanation for the coefficient (StataCorp., 2019). Therefore, we added floor area as an independent variable in the selection model, which is not in the outcome model.

#### 3.3.2. Second stage variables (long-distance commuting)

The dependent variable in the second stage indicates whether the residents be the long-distance commuters, and we chose >45 min as an indicator of long-distance commuting. The median commuting time is 30 min in the inner city and 20 min in the outer. 80% of commutes in inner and outer cities are <45 min. Our key independent variable of interest is *hukou* and occupation. We divided the occupation into three groups: blue-collar workers, pink-collar workers, and white-collar workers. Blue-collar workers are production workers and transport equipment operators; pink-collar workers are business and service personnel; and white-collar workers are unit heads, professional and technical experts, and clerks and related workers. Other influencing factors, including jobs-housing balance (Zhao et al., 2010), population density (Zhao et al., 2010), gender (Newbold et al., 2017), housing status (Helderman et al., 2004), household size (Dargay and Clark, 2012; Schwanen and Mokhtarian, 2007), household composition, households with children (Hong et al., 2018), education level (Cassel et al., 2013), and car ownership (Champion et al., 2009; Limtanakool et al., 2006) are selected as our control variables.

## 4. Results

Consistent with our theoretical hypothesis, the empirical analysis adopts a two-step model. In the first stage, the residential choices of

**Table 1**
Summary statistics of explanatory variables.

| Variables | Description | Mean/ proportion | Std. Dev. | Min | Max | Step |
|---|---|---|---|---|---|---|
| Locational variables | | | | | | |
| Population density | The net density of population where a worker lives in the TAZ (10,000 persons/km$^2$) | 1.946 | 1.390 | 0.000 | 6.407 | Step 2 |
| Employment–population ratio | The distribution of employment relative to the distribution of population in the TAZ | 0.521 | 0.177 | 0.311 | 2.047 | Step 2 |
| Socioeconomic variables | | | | | | |
| Gender | Male (reference) | 56.71% | | | | Step 1/ step 2 |
| | Female | 43.29% | | | | |
| Education level | Without college degree (reference) | 74.73% | | | | Step 1/ step 2 |
| | With college degree | 23.37% | | | | |
| | Master's degree or higher | 1.90% | | | | |
| Household size | Number of household members | | | | | Step 1/ step 2 |
| Household composition | One-worker household | 14.37% | | | | Step 1/ step 2 |
| | Two-worker household | 63.14% | | | | |
| | Three or more-worker household | 22.49% | | | | |
| Households with children | No children (reference) | 84.04% | | | | Step 1/ step 2 |
| | With children | 15.96% | | | | |
| Housing status | Owner-occupied housing (reference) | 66.60% | | | | Step 1/ step 2 |
| | Rental housing | 32.25% | | | | |
| | *Danwei* housing | 1.14% | | | | |
| Car ownership | Without car | 55.67% | | | | Step 1/ step 2 |
| | With car | 44.33% | | | | |
| *Hukou* | Local (reference) | 68.20% | | | | Step 1/ step 2 |
| | Migrant | 31.80% | | | | |
| Age | Age | 35.857 | 8.912 | 16 | 70 | Step 1/ step 2 |
| Occupation | Blue-collar worker | 16.15% | | | | Step 1/ step 2 |
| | Pink-collar worker | 30.63% | | | | |
| | White-collar worker (reference) | 53.22% | | | | |
| Floor area | Floor area (in square meters) of the housing unit | 97.136 | | | | Step 1 |

residents living in the outer districts were endogenized. In the second stage, the estimated probability of not living in the outer districts is used as a regressor to analyze the possibility of being a long-distance commuter. The variance inflation factor values of each model are <5, indicating that there is no multicollinearity issue. Table 2 presents the selection results for the choice of living in the outer districts.

In terms of control variables, the results show that education level, car ownership, and age is negatively related to living in the outer districts. Higher education levels reduce the likelihood of living in the outer districts, as most knowledge-intensive jobs are concentrated in the city center (Tran et al., 2016). Households with private cars are more likely to live in the inner districts, as those who live in the inner districts tend to have higher income levels. In China, older groups are more likely to live in old urban areas while younger groups are migrated to the suburbs (Liu and Zhang, 2006; Wu et al., 2002).

The more complex the composition and structure of households, the more likely they are to live in the outer districts. Schwanen and Mokhtarian (2007) found that household sizes, presence of children, and dwelling sizes are positively related to living in suburban area. This result is consistent with our results, suggesting that the effects of these factors are consistent across countries. Compared to the homeowners, renters and households living in the *danwei* housing are less likely to live in the outer districts. This result is consistent with previous studies on the comparison between renters and homeowners (Cao et al., 2009). Regarding *danwei* housing, since the disintegration of the *danwei* system preceded the development of outer districts, most *danwei* housing is located in the inner districts.

For our focus variables, the main effect shows that migrants (a coefficient of 0.207) are more likely to live in the outer districts. It indicates that migrants are being excluded from urban centers. Blue-collar workers (a coefficient of 0.553) are more likely to live in the outer districts than white-collar workers since industrial suburbanization attracted many blue-collar workers to reside there. The difference in the residential choice between pink-collar workers (a coefficient of 0.058) and white-collar (a coefficient of 0) is rather small, as both pink-collar jobs and white-collar jobs are concentrated in the inner districts (Li et al., 2022).

The interaction effect shows that the effect of *hukou* changes with occupation. Blue-collar (0.553 + 0.207–0.015 = 0.745) and white-collar migrants (0 + 0.207 + 0 = 0.207) are more likely to live in the outer districts than blue-collar locals (0 + 0.553 + 0 = 0.553) and white-collar locals (0). For blue-collar workers, this is because the secondary industrial transfer in the 1990s and 2000s made a large number of industries gathered in the outer districts, attracting a large number of migrants to rent houses around the industrial zone. For white-collar workers, the migrants cannot afford higher housing prices in the inner districts and therefore choose to live in the cheaper outer cities.

Table 3 presents the results of the regression analysis of long-distance commuting (in the outer districts and the inner districts). Two separate regressions were estimated for long-distance commuting: one used the sub-sample of residents living in the outer districts and the other one used the sub-sample of residents living in the inner districts.

Model 2–1 shows the results of long-distance commuting (second stage) by workers who reside in the outer districts. The coefficient rho[4] of the test for independence of equations is statistically significant at the 0.01 level, indicating that living in the outer districts is pertinent to long-distance commuting.

In terms of our control variables, population density, gender, education level, housing status, and age are correlated to long-distance commuting. The probability of long-distance commuting is lower for females (a coefficient of −0.222). In accordance with previous studies, higher education levels increase the probability of long-distance

[4] Rho—which is the correlation between the regression and the selection equation—is bound between −1 and 1.

**Table 2**
Binary probit model for living in the outer districts (first stage).

| | Model 1–1 | |
|---|---|---|
| Variables | Coef. | Robust SE |
| Gender (ref: male) | | |
| Female | −0.017 | 0.014 |
| Education level (ref: without college degree) | | |
| With college degree | −0.437*** | 0.018 |
| Master's degree or higher | −0.755*** | 0.059 |
| Household size | 0.002 | 0.008 |
| Household composition (ref: one worker) | | |
| Two-workers | 0.432*** | 0.03 |
| Three or more | 0.195*** | 0.023 |
| Households with children | 0.101*** | 0.02 |
| Floor area | 0.006*** | 0.000 |
| Housing status (ref: owner-occupied) | | |
| Rental | −0.274*** | 0.026 |
| *Danwei* | −0.702*** | 0.084 |
| Car ownership | −0.144*** | 0.016 |
| Age | −0.009*** | 0.001 |
| *Hukou* (ref: local) | | |
| Migrant | 0.207*** | 0.03 |
| Occupation (ref: white) | | |
| Blue | 0.553*** | 0.029 |
| Pink | 0.058*** | 0.019 |
| *Hukou*×Occupation | | |
| Migrant×Blue | −0.015 | 0.043 |
| Migrant×Pink | −0.257*** | 0.036 |
| Constant | −0.613*** | 0.046 |
| Observations | 36,270 | |

Note: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

**Table 3**
Binary probit model for long-distance commuting (second stage).

| | Living in the outer districts | | Living in the inner districts | |
|---|---|---|---|---|
| | Model 2–1 | | Model 2–2 | |
| Variables | Coef. | Robust SE | Coef. | Robust SE |
| Population density | 0.039** | 0.016 | −0.009 | 0.008 |
| Employment–population ratio | 0.112 | 0.116 | −0.019 | 0.05 |
| Gender (ref: male) | | | | |
| Female | −0.222*** | 0.027 | −0.110*** | 0.021 |
| Education level (ref: without college degree) | | | | |
| With college degree | 0.326*** | 0.043 | 0.012 | 0.03 |
| Master's degree or higher | 0.394*** | 0.130 | 0.107 | 0.068 |
| Household size | 0.001 | 0.014 | 0.039*** | 0.012 |
| Household composition (ref: one worker) | | | | |
| Two-workers | 0.047 | 0.064 | 0.024 | 0.047 |
| Three or more | −0.015 | 0.051 | 0.009 | 0.031 |
| Households with children | −0.070* | 0.037 | −0.018 | 0.031 |
| Housing status (ref: owner-occupied) | | | | |
| Rental | −0.226*** | 0.063 | −0.149*** | 0.038 |
| *Danwei* | −0.738*** | 0.285 | −0.078 | 0.083 |
| Car ownership | −0.050* | 0.03 | −0.225*** | 0.024 |
| Age | −0.014*** | 0.002 | 0.000 | 0.001 |
| *Hukou* (ref: local) | | | | |
| Migrant | 0.188*** | 0.061 | −0.003 | 0.04 |
| Occupation (ref: white) | | | | |
| Blue | −0.046 | 0.05 | 0.256*** | 0.056 |
| Pink | −0.016 | 0.037 | −0.070** | 0.031 |
| *Hukou*×Occupation | | | | |
| Migrant×Blue | −0.295*** | 0.08 | −0.282*** | 0.069 |
| Migrant×Pink | −0.026 | 0.074 | 0.028 | 0.05 |
| Constant | −0.778*** | 0.116 | −0.672*** | 0.094 |
| Observations | 15,142 | | 21,015 | |
| rho | 0.143** | 0.073 | −0.248*** | 0.073 |

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

commuting, as jobs requiring higher education are scarcer and their distribution is more concentrated, resulting in longer commutes for well-educated people (Cassel et al., 2013). In addition, the probability of long-distance commuting is lower for residents living in rental or *danwei* housing, because low transaction costs allow renters to move closer to work (Dieleman, 2001; Helderman et al., 2004). In addition, age (a coefficient of −0.014) is negatively related to long-distance commuting.

In terms of our focus variables, the main effect shows that migrants (a coefficient of 0.188) are more likely to be long-distance commuters. Since migrant workers are less likely to use private cars than locals (Li et al., 2021), they are more likely to take longer commutes than the locals.

The interaction effect shows that the effect of occupation changes with *hukou*. Pink-collar migrants (0.188–0.016-0.026 = 0.146) and white-collar migrants (0.188 + 0 + 0 = 0.188) are more likely to be long-distance commuters than pink-collar locals (−0.016) and white-collar locals (0). In contrast, blue-collar migrants (0.188–0.046-0.295 = −0.153) are less likely to be long-distance commuters than blue-collar locals (−0.046).

Model 2–2 shows the results of long-distance commuting by workers who reside in the inner districts. The coefficient rho of the test for independence of equations is statistically significant at the 0.01 level, indicating that living in the inner districts is pertinent to long-distance commuting.

In terms of our control variables, gender and housing status are correlated to long-distance commuting, and the positive and negative effects of these factors are consistent with Model 2–1. In the inner district, car ownership negatively affects long-distance commuting, since having a car can greatly reduce travel time when the distance is fixed.

With respect to our focus variables, the effect of occupation and *hukou* is different from those of living in the outer districts. The main effect shows that *hukou* has no influence on long-distance commuting in the inner districts. Regarding occupation, blue-collar workers (a coefficient of 0.256) were most likely to be long-distance commuters, while pink-collar workers (a coefficient of −0.070) were least likely.

The interaction effect shows that the effect of occupation changes with *hukou*. For pink-collar and white-collar workers, there is little difference between locals and migrants in long-distance commuting in the inner districts. In terms of blue-collar workers, migrants (−0.003 + 0.256–0.282 = −0.029) are less likely to be long-distance commuters than blue-collar locals (0.256). This is because the relocation of blue-collar jobs in the inner districts has increased the likelihood of long-distance commutes for local blue-collar workers. In contrast, most blue-collar migrants rent a house in the vicinity of the industrial zones and are therefore less likely to be long-distance commuters.

## 5. Conclusions

Most current research on long-distance commuting focuses on Western countries. In the Chinese context, the *hukou* system and occupational need to deserve attention. However, few studies have focused on the individual and the interaction effect of these two factors on long-

distance commuting. This paper analyzes the differences in residential location choices and long-distance commuting between different socioeconomic groups from the perspective of spatial mismatch. A two-step model was used to examine the residential choice (step 1) and the long-distance commuting behavior (step 2). Through this approach, the determinants and underlying mechanism of a spatial mismatch for different socioeconomic groups were estimated.

The results show that the effects of socioeconomic factors on long-distance commuting are consistent with those in western countries. Female, older people, and renters are less likely to be long-distance commuters, both in Western countries and in China. In contrast, education level has a positive effect on long-distance commuting, since jobs requiring higher education are fewer and more concentrated, resulting in longer commutes for well-educated people (Cassel et al., 2013).

The main finding of this study is that suburbanization, especially the continued suburbanization of blue-collar jobs in the last 20 to 30 years, has different effects on the housing choice and commuting of individuals with different occupations and *hukou*. The continued suburbanization of the industry attracted substantial numbers of blue-collar workers to live in the outer districts. On the contrary, the abundant job opportunities in the inner city made pink-collar and white-collar workers tend to live in the inner districts. Regarding *hukou*, migrants (a coefficient of 0.112) are more likely to live in the outer districts than locals. It indicates that migrants are being excluded from urban centers. The interaction effect shows that the effect of *hukou* changes with occupation. Blue-collar (a coefficient of 0.745) and white-collar migrants (a coefficient of 0.207) are more likely to live in the outer districts than their local counterparts (the coefficients of 0.553 and 0, respectively). For blue-collar workers, this is because industrial relocation attracted more migrants than locals, who have higher residential mobility than their local counterparts. For white-collar workers, the migrants cannot afford higher housing prices in the inner districts and therefore choose to live in the cheaper outer cities.

The distribution of residence and employment among different groups, as well as their preference for different modes of travel, cause inconsistencies in long-distance commuting. Among residents of the outer districts, blue-collar migrants (a coefficient of −0.153) and locals (a coefficient of −0.046) are less likely to be long-distance commuters than other groups, in contrast to the results in U.S. cities (O'Kelly and Lee, 2005). Among residents of the inner districts, blue-collar locals (a coefficient of 0.256) are more likely to be long-distance commuters than blue-collar migrants (a coefficient of −0.029). Again, this is due to industrial suburbanization that began in the 1990s, which turned them into long-distance commuters. Furthermore, pink-collar migrants (a coefficient of −0.045) are more likely to be long-distance commuters than blue-collar migrants.

This result provides the foundation for predicting the future development of the city, in particular the future development under the continuous urban renewal of the inner districts and the continuous development of the outer districts. To accelerate the construction of the Western Taiwan Straits Economic Zone (or West Coast Economic Zone), the Xiamen government is committed to developing a "cross-strait financial center" in the eastern part of Xiamen Island, which will result in the demolition of urban villages and the replacement of low value-added industries with high value-added ones. Inevitably, this will push low-income migrants to the outer cities. Besides, population growth occurs almost in the outer districts, while many white-collar and pink-collar jobs are still concentrated in the inner districts (Li et al., 2022). In the near future, the spatial mismatch between pink- and white-collar workers in the outer districts and pink- and white-collar jobs in the inner districts inevitably makes these groups become long-distance commuters.

Concerning policy implications, the results suggest that the potential spatial mismatch for pink- and white-collar workers and migrants displaced by demolition should be alleviated in three ways. First, the efficient public transportation of long-distance travel should be built to connect the inner and outer districts to solve the increasingly serious spatial mismatch. Second, the demolition of urban villages should be compensated by affordable social housing for the benefit of migrants in the inner districts. Under the existing housing system, the potential displaced migrants in the inner districts cannot get preferential policies such as low-rent housing. Thus, the redevelopment of urban villages only benefits the housing owners and makes the migrant population living in urban villages homeless. This will inevitably lead to migrants moving to outer cities to become long-distance commuters, or even to other cities. Social housing policies, especially those concerning low-cost housing, should therefore be extended to the migrants. Third, a certain proportion of white-collar and pink-collar jobs should be arranged in the outer districts.

Our analysis has certain limitations. First, data restrictions prevented us from assessing the impacts of income on long-distance commuting. Second, the Heckman probit selection model was difficult to quantitatively explain the marginal effect of results due to the existence of interaction terms (Williams, 2012). Instead, the results could only report the positive and negative effects of different independent variables on long-distance commuting.

## CRediT authorship contribution statement

**Yongling Li:** Formal analysis, Methodology, Writing – original draft. **Stan Geertman:** Conceptualization, Writing – review & editing, Supervision. **Pieter Hooimeijer:** Conceptualization, Writing – review & editing, Supervision. **Yanliu Lin:** Writing – review & editing, Supervision. **Haoran Yang:** Methodology, Conceptualization, Writing - review & editing. **Linchuan Yang:** Writing – review & editing.

## Data availability

The authors do not have permission to share data.

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