

INTRA-URBAN WAGE VARIATION IN BEIJING: HAS COMMUTING TIME BEEN WELL CAPITALIZED?

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ABSTRACT

In a well-functioning metropolitan area, firms whose workers have long commutes will have to compensate them with appropriately higher wages to attract enough labor. Whether this hypothesis holds true in Chinese cities where urban spatial structure, wages, and housing markets are undergoing dramatic transformation remains an open question. Taking advantage of a matched data structure from a large-scale survey that incorporates the information of where workers live and work, we empirically examine whether workers receive higher wages commensurate with higher commuting costs, and if so, by how much. The results show that workers' commuting cost differentials have been well capitalized into wages in Beijing. On average, the cost of travel (time plus commuting cost) is about 2.1 times the

wage rate (for that amount of time). Therefore, employment decentralization can effectively reduce firms' labor cost and hence increase their productivity, especially in the current period of fast suburbanization of residential land use. Whether firms pay higher compensation because of agglomeration benefits is still in need of further investigation.

INTRODUCTION

The capitalization of commuting costs and accessibility to various kinds of urban amenities into land rents has been well investigated in urban economic spatial models. In recent years, scholars have also addressed the relationship between wages and commuting costs - that during the job decentralization process, if firms are located at different points within a metropolitan area, transportation costs must be capitalized into wages as well.

Empirical studies in this area mostly focus on estimating a wage gradient, theoretically hypothesized by Moses (1962). The basic idea is that systematic spatial variation in land prices—rent gradients—and in wages—wage gradients—is necessary for urban spatial equilibrium (Moses, 1962; Mills, 1972; Muth, 1969). Firms should make wage compensation to workers to cover their commuting cost if they want to attract workers who live farther away. From a worker's perspective, and given where he/she lives, the equilibrium requires that the commuting cost differentials and wage differentials should make him/her indifferent to the location of different workplaces.

However, the number of empirical studies on intra-urban wage variation is far less than that on urban rent gradients, even in the United States, partly because of the difficulty in obtaining good micro data matching workplace-liveplace information with data on human capital characteristics. Early studies, like Segal (1960), use aggregate data to study wage gradients for some industries. The uncontrolled worker characteristics that would vary systematically across space and the lack of observations reduce the rigor of such studies. Eberts (1986) tries to overcome this problem by focusing on specific employment types in the public sector, but individual productivity still could not be controlled. He finds that negative wage gradients are found for four of the five labor groups of municipal public employees in the Chicago SMSA. Madden (1983) starts to use micro data to study wage gradients. Based on national longitudinal data on house and/or job changers, he finds systematic wage gradients exist in American cities that are consistent with monocentric model. Ihlanfeldt (1990) uses 1980 micro data in Philadelphia, Detroit and Boston metropolitan area to test wage variation in a monocentric model, and finds significantly negative wage gradients for white workers but positive wage gradients for black workers, which supports the spatial mismatch hypothesis that blacks have been disadvantaged by job suburbanization and housing market segregation. McMillen and Singell (1991) also uses micro data for 7 cities from the 1980 census to test the monocentric model by estimating wage gradients with predicted work locations derived from a probit choice model.

Departing from previous studies that mostly lie in the monocentric world and have "1-dimensional" wage gradients, Timothy and Wheaton (2001) turn to the "2-dimensional" context. They use microdata from the 1990 census for Boston and Minneapolis and take advantage of the definition of place-of-work PUMAs (Public Use Microdata Areas) to divide each metropolitan area into about 20 work zones. They incorporate the average commuting time in each zone into the wage equation to examine whether the commuting cost differentials are capitalized into wages. Their empirical result supports such hypothesis and the elasticity of wages with respect to zonal commuting times is largely consistent with the value of travel time. They also mention that whether such wage differences result from equilibrium agglomeration effects or from a disequilibrium of employment distribution is still an inconclusive question.

As far as we know, rigorous study on intra-urban wage variation and commuting cost capitalization has not emerged in China yet. Therefore, the first purpose of this paper is to test whether this hypothesis holds in Chinese cities (we use Beijing as a case), and if so, to what extent it holds. Our rationale for wanting to test this is that certain fundamental assumptions of the "compensation" argument are still open to question in Chinese cities. One such assumption is that firms should follow cost-minimizing behavior when choose where to locate. They may be able to afford or be willing to pay higher wages because they enjoy some benefit from not locating close to their workers such as agglomeration economies. Another basic assumption is that households are also mobile and follow the utility-maximizing behavior. Given where they live, they would require higher payment if they need to commute further.

Such assumptions did not hold at all in Chinese cities before the 1980s. In that planned economy era, the nation had standard wage systems in urban areas, in which the individual's wage was a fixed function of his/her office ranking, occupational status and working experience, with zero wage gradient across space. At the same time, each firm used part of its land to build dwellings by itself and distribute

them at an extremely subsidized rent to its employees, so workers would commute by foot or bicycle to work near their home. Such conditions have changed dramatically since China reinstated the urban land market in the late 1980s and started numerous economic reforms. Wages and land rent become more market-oriented, and downward slopes from the traditional city centers began to emerge (more detailed description can be found in Section 2). But the relative immobility of existing fixed structures and the transitional nature of the housing market are still to a great extent hindering the reallocation of urban space according to those basic market criteria. More importantly, if this principle still holds in China, we can further argue that encouraging firms to locate near their labor force, or improving the condition of jobs-housing balance, can effectively reduce commuting cost and labor cost, thereby improving the efficiency of urban economy.

The second purpose of this paper is to examine whether different population groups can all be compensated reasonably based on their commuting costs. The elasticities of wages with respect to commuting times are calculated for different sub-groups and compared to their values of time.

We also try to question why firms prefer to cluster together and pay higher wage compensation for longer commutes rather than moving to suburban locations closer to their workers. Does agglomeration play an important role, or does the firm's historical location and institutional barriers to moving still contribute a lot to the firm's location pattern?

We proceed with the following section. In section 2, we describe our unique dataset and provide the institutional background of urban spatial structure in Beijing. Our models are introduced and empirical results are listed and discussed in section 3. We conclude in section 4 and make an agenda for next step's research.

DATA AND URBAN SPATIAL STRUCTURE IN BEIJING

Survey and Data

The data in this paper comes from a large-scale survey conducted by Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Science, in Beijing, during August and September, 2005. A pair of matched records of where each worker works and where he/she lives is a distinguished merit of this sample. The sample size is about 4700 after excluding uncompleted and unauthentic questionnaires.

The sampling method of this micro dataset was carefully designed and implemented. To explain our sampling method, we begin with a brief description of the administrative system in Beijing city. This system has three levels: Municipality, District and Community. There are 16 Districts in Beijing, but some remote ones are actually rural area. Conventionally, the municipal government and the public use ring roads as a convenient way to define the urbanized area. Five ring roads (No. 2 to No. 6) have been built from the city center outward, and most urbanized area is within No. 5 ring road, while there is little urban activity beyond No. 6 ring road. Therefore, the spatial range in this survey was defined to be the area within No. 6 ring road (we call it "the urban area" thereafter). This includes 8 whole Districts and a small part of the 9th District. Within this urban area, 120 Communities exist as the fundamental administrative organizations (the average size of each Community is about 2220 acres). The most recent 2000 census reported the population distribution over these Communities. Using Community as the basic unit, this survey chose the number of observations in each Community proportionally to its population. Within each Community, streets and then buildings were randomly selected, and people in those buildings were interviewed on a random basis.

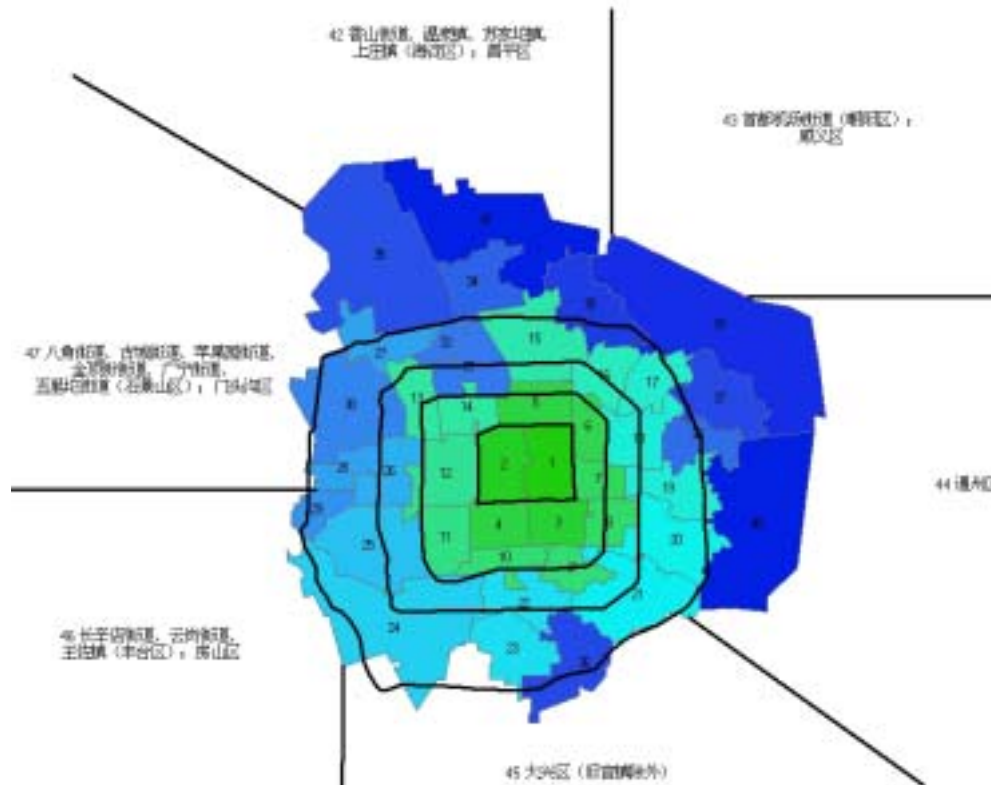
The information used in this paper comes from three sections in that questionnaire. The first section includes two location variables for where he/she works and lives. This information is precise to the Community level. The second section is about commuting and housing information, e.g., commute mode and one-way time, house size and type, purchase year and price. The third section includes some demographic characteristics of the respondent and his/her family, e.g., the respondent's age, gender, education level, occupation, the household's size and monthly income.

In order to reduce noise and improve estimation efficiency, we combine those 120 communities into 41 zones according to their locations and sizes, with each zone comprising approximately 3 adjacent Communities. We notice that there are still some scattered observations that fall out of this scope, so another 6 fringe zones are created to cover the area from the outer boundary of these 41 zones to the outer urban fringe in each direction. The average number of observations in each zone is around 100,

and those zones further away from city center have larger area sizes (Figure 1).

Figure 1. 47 ZONES IN BEIJING

Source: Author



To further clean up our data, we exclude those observations without current employment (retired, student, unemployed, etc.), because they do not have valid workplace information. We also exclude the records that have obvious data mistakes by examining outliers in the descriptive analysis. 5 remote zones (zone No. 29, 36, 41, 42, 43) are dismissed because no observation in those zones passes this filtering process. Finally 42 zones and 4345 valid observations are left, and Table 1 shows the descriptive statistics of this sample.

Table 1. DESCRIPTION OF THE VARIABLES AND SUMMARY STATISTICS

Variable	Definition	Sample Mean (Std. Dev.)	No. of obs.
COMT	One-way commuting time of respondent (minute).	37.51 (24.75)	4306
INCOME	Monthly household income of the respondent's family (RMB). 1=less than 3,000; 2=3000-4999; 3=5000-9999; 4=10,000 and above.	2.21 (0.91)	4345
INCT	Continuous variable of income, transformed from INCOME. INCT=2,000 when INCOME=1; INCT=4,000 when INCOME=2; INCT=7,500 when INCOME=3; INCT=12,000 when INCOME=4.	5,190 (2,913)	4345
GENDER	Binary: gender of the respondent. 1=male; 0=female.	0.50 (0.50)	4345
AGE	Age of the respondent (years): 1= below 30; 2= 30~39; 3=40~49; 4=50+.	2.03 (1.03)	4345
HHSIZE	Household size (number of people).	2.59 (0.98)	4345
EDU	The highest education level the respondent archived. 1=junior high school or below; 2=senior high school; 3=undergraduate; 4=graduate or above.	2.68 (0.68)	4345
VHC1	Binary: commute mode being walking.	0.12 (0.32)	4345

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VHC2	Binary: commute mode being bicycling.	0.22 (0.41)	4345
VHC3	Binary: commute mode being public transit.	0.52 (0.50)	4345
VHC4	Binary: commute mode being private transportation (driving or taking cab).	0.15 (0.35)	4345
DWTYPE1	Binary: dwelling type being work-unit housing (have/haven't privatized).	0.52 (0.50)	4345
DWTYPE2	Binary: dwelling type being newly built economy-housing.	0.13 (0.34)	4345
DWTYPE3	Binary: dwelling type being newly built commodity housing.	0.24 (0.43)	4345
DWTYPE4	Binary: dwelling type being privately rental housing.	0.10 (0.31)	4345
HAREA	Floor area of the respondent's house (square meter).	75.5 (32.2)	4323
OCCUP1	Binary: occupation being employees in public sector (mostly civil servants and teachers).	0.18 (0.39)	4345
OCCUP2	Binary: occupation being professionals (mostly IT, finance and insurance, consulting and real estate).	0.32 (0.46)	4345
OCCUP3	Binary: occupation being employees in industrial firms.	0.22 (0.41)	4345
OCCUP4	Binary: occupation being employees in service industry.	0.11 (0.32)	4345
OCCUP5	Binary: occupation being self-employed.	0.17 (0.37)	4345
WZONE1~ WZONE42	Work zone dummies to indicate where the respondent works, 42 zones.	Averagely 120 in each zone	4345
HZONE1~ HZONE42	Home zone dummies to indicate where the respondent lives, 42 zones.	Averagely 120 in each zone	4345
IDINCT	Household monthly income (RMB) of identical worker in each zone, calculated from Equation (3).	6,215.39 (673.08)	42
IDCOMT	Commuting time (min) of identical worker in each zone, calculated from Equation (2).	43.07 (6.86)	42
NJOB	The number of jobs in each zone.	118.36 (102.73)	42
JHR	The ratio of the number of jobs and the number of houses in each zone.	1.60 (1.90)	42
MIX	Mix measure calculated from Equation (5).	0.22 (0.15)	42

The average one-way commuting time is 37.5 minutes in Beijing, which is longer than Boston (26.9 min), Minneapolis (22.5 min) and also Chicago (32 min) (Timothy and Wheaton, 2001; Chicago Metropolis 2020, 2006). While most previous studies have data on workers' wages, we can only get household income from the survey, which definitely weakens the direct relationship between the worker's income variable and his/her commute. Nevertheless, two-worker households (husband and wife) are quite common in Beijing, and the two workers usually have similar background and education achievement, so household income still can serve as a good proxy for wage level. Most respondents belong to the first three categories along the income spectrum. Households earning monthly income less than 3000 RMB (US\$ 375), 3000~4999 RMB (US\$ 375~625) and 5000~9999 RMB (US\$ 625~1250) account for 25%, 38% and 29% of the whole sample, respectively. 68% of the respondents have the highest education level of college or above, showing that the worker skills have been improved dramatically in large Chinese cities like Beijing.

Table 2. COMMUTE MODE AND TIME ACROSS INCOME GROUPS

Commute mode	Monthly Household Income				Sum
	(1) <3,000 RMB	(2) 3,000~4,999 RMB	(3) 5,000~9,999 RMB	(4) 10,000+ RMB	
A. Walk	17% [13.2 min]	11% [12.8min]	8% [13.9 min]	11% [12.4 min]	12% [13.1 min]
B. Bicycling	30% [26.1 min]	22% [25.0 min]	17% [25.8 min]	12% [26.0 min]	22% [25.6 min]
C. Public Transit	48% [50.1 min]	56% [49.2 min]	53% [46.6 min]	40% [47.9 min]	52% [48.5 min]
D. Private transportation	5% [36.2 min]	10% [37.0 min]	22% [33.8 min]	37% [33.1 min]	15% [34.7 min]
Sum	100% [36.1 min]	100% [38.6 min]	100% [37.8 min]	100% [35.9 min]	100% [37.5 min]

Note: The first number (in percentage) in each cell is the share of respondents using the commute mode in this income category; the second number in square bracket is the average commuting time for the income group in each commute mode.

More interestingly are the commute modes in Beijing. Approximately half of our respondents choose public transit, including bus and subway. The second most popular transportation method is bicycling, accounting for 22% of the total sample. Walking and private transportation have similar shares. Table 2 compares commute mode choice and time among different income groups. Average commuting times for different commuting modes show high diversification: public transit takes the longest time (near 50 minutes) and walking only takes 13 minutes. Regarding the choice of commute mode, rich people tend to use more private transportation, much less bicycling, and slightly less walking and public transit. While we do not find large variation in commuting times across the income spectrum, in section 3 we will find more significant differences after controlling for other demographic characteristics and workplace.

Descriptive Analysis of Urban Spatial Structure and Labor Market in Beijing

Here we briefly review the development of the urban form and changes in the urban labor market in China to give a better context for our empirical study.

Before the 1980s, Chinese cities in the planned economy were typically very compact with a predominantly mixed pattern of residential and non-residential land uses (Sit, 1985). The majority of the urban workforce would commute by foot or bicycle to work near their home. However, the old central areas of Chinese cities were always the commercial, cultural and administrative hub, even during the period of the planned economy.

After forty years of a planned economy, China reinstated the urban land market in the early 1990s as it opened its economy more fully to foreign direct investment. The real estate market took off, massive land redevelopment took place and the service sector experienced a rapid growth in many Chinese cities. A more specialized land-use pattern has emerged: the central business district (CBD) has greatly expanded and the residential land use has been extended into suburbs, whereas industrial land use has been pushed towards the outlying urban locations. At the same time, land-rent gradients sloping down from the traditional city centers also emerge in the land market, and high-paid job opportunities have tended to concentrate in and around city centers. Employment subcenters also emerge in large cities, where similar or complementary industries cluster together to enjoy some kinds of agglomeration benefits. In Beijing, for example, people can find the IT subcenter (Zhong Guan Cun) and the bank subcenter (Jin Rong Jie) adjacent to the main CBD where most international company headquarters, consulting firms and financial companies locate. These remarkable transformations in urban spatial structure at the macro level demonstrate the powerful market force at work in Chinese cities.

The urban housing sector has also undergone a dramatic reform. Before 1980, urban housing in China was allocated to urban residents as a welfare good by their employer (the work unit) through the central planning system. Workers enjoyed different levels of housing welfare according to their office ranking, occupational status, working experience and other merits. Residents had little opportunity to choose their residential location according to their income and other household characteristics in the absence of the housing market. Since the early 1980s, most of the work-unit housing complexes have been privatized—sold to the sitting tenants. By the end of the 1990s, housing procurement by work units for their employees had officially ended and new homes would be built and sold in the market. Developable land was supplied and regulated by the government through long-term leases (Fu, et. al. 2000; Fu and Somerville, 2001). Large numbers of old homes in central urban areas were demolished to make way for new transport infrastructure, commercial development and up-market housing projects. Built-up urban areas were quickly expanded and new mass housing projects (including economy-housing projects built on subsidized land) were built primarily around the fast expanding urban fringe.

Despite the remarkable change in urban form and the increasing liberalization of the housing and urban land markets in the 1990s, there still remain some hindrances in the market that prevent a Pareto-efficient spatial sorting. Zheng, Fu and Liu (2006) suggest three main hindrances: the resale housing market is slow to develop, housing finance is limited and the supply of affordable housing is skewed towards the urban fringes.

Our data also gives some evidence on these stylized facts. Table 3 shows the composition of the Beijing housing sector in which about half of the units are work-unit housing, either sold out to their sitting tenants at non-market and deeply subsidized prices (but not resold on the market) or still leased out by

work units. In both cases, such houses (and locations) still follow the resource allocation principle in the planned economy, and have not been reallocated according to the willingness-to-pay or bid-rent functions of household groups in the market. Residents in this type of dwellings have the shortest commuting time, mainly because such houses were built before the economic reforms were introduced. At that time the built-up area in the city was still small, and therefore they occupied more central locations. Another reason shorter commutes is that a large part of the residents who live in such houses are still working in nearby work units. Such a large fraction of non-market allocation of residential land brings many hindrances to urban spatial efficiency.

Residents in newly built economy-housing (always low- and moderate- income households) have the longest commuting times due to the fringe locations of such projects where developers have been able to get subsidized land parcels from local government. Newly built commodity housing projects are scattered throughout the urban built-up area where developers can find vacant or demolished land parcels. Nevertheless, most of them are also on the newly formed urban area far away from the city center.

Privately-built rental housing only counts for a small fraction of total units in the housing sector. An important concept here is that different housing choice opportunities exist for different population groups. Only the old generation of original residents has the opportunity to occupy work-unit housing, while their children as well as immigrants from other cities and rural areas can only choose housing in the other 3 categories. Economy-housing is aimed at low- and moderate-income households but the lack of a credit system and strong regulation make the income restrictions on who lives in economy housing difficult to enforce. .

Table 3. DWELLING TYPES AND COMMUTING TIMES

	Dwelling type			
	Work-unit housing (have/haven't privatized)	Newly built economy-housing	Newly built Commodity housing	Privately Rental housing
N. of obs. (share in %)	2257 (52.4%)	575 (13.4%)	1023 (23.8%)	451 (10.5%)
Average Commuting time (in min)	36.1	45.0	38.6	32.7

The standard wage system in the planned economy also changed dramatically since 1980s. The private sector has been growing very fast in the urban economy. Taking Beijing as an example, the share of employees in the public sector (state-owned companies and non-profit institutions) dropped from 53.8% in 1995 to 23.4% in 2004¹. Firms in the private sector have full flexibility in determining their own wage systems, and wage and true human capital levels have been tightly connected. With the “modern enterprise system” widely introduced into the public sector to improve its productivity, the wage system has also been reformed to better represent labor productivity. Therefore, the current wage system in Chinese cities is much more market-oriented. However, there is still no empirical study to answer questions such as what does the intra-urban spatial pattern of wage look like, or to what extent do the newly emerging wage differentials reflect commuting cost variations across space.

MODELS AND EMPIRICAL RESULTS

Models

We use several ways to test whether commuting cost has been systematically and consistently capitalized into workers' wages. Some of our tests are more intuitive while others control for human capital and housing characteristics. Our basic unit for spatial analysis uses the 42 zones described above (zone IDs range from 1 to 47; Zones 29, 36, 41, 42, 43 are excluded).

(1) Average zonal commuting times and wage levels

Intuitively, we expect that wage levels in those work zones vary systematically with commuting times that workers spend to get to those zones. To test these relationships, we calculate the average wage level and commuting time in each work zone, and run the simple regression in Equation (1), to see if there exists any significant correlation between these two averages.

¹ Beijing Statistic Yearbook, 1996–2005.

$$\overline{INCT}_i = \alpha_1 + \alpha_2 \cdot \overline{COMT}_i \quad (1)$$

Where, i is the work zone ID. The coefficient of α_2 is expected to be significantly positive, meaning that workers in those zones with relatively higher commuting times (less-reachable zones) need more compensation in their wages to cover travel costs. We have altogether 42 observations in this equation.

(2) Log-linear wage equation and commute equation with zone dummies

Clearly we do not control for all the human capital factors that will influence wage level in Equation (1), so systematic variation of such human capital characteristics across space will bias the results. For example, rich people may like to live further away from the city center and also have higher wages (whether this phenomenon is true in Chinese cities still needs empirical test), or higher-educated workers may have to commute further in order to find matched job opportunities due to the thinner labor market. This is exactly the point being criticized when macro data is employed in similar studies on intra-urban wage variation. (See Madden, 1983, Ihlanfeldt, 1990, McMillen and Singell, 1991) Our dataset has the merits of micro and matched job-housing location structure, which makes it quite easy to control for human capital and other factors aside from pure location that affect wage and commuting patterns.

Firstly, we estimate commuting times using Equation (2):

$$\ln(\overline{COMT}_k) = c + \alpha' X_k + \beta' VHC_k + \gamma' DWTYPE_k + \eta' Z_k, \quad (2)$$

$$k = 1, \dots, K$$

Where,

\overline{COMT}_k = one-way commuting time of the respondent k

X_k = a vector of demographic variables, including GENDER, AGE, INCT, HHSIZE, EDU, OCCUP2~OCCUP5 (OCCUP1, public sector, is the default).

VHC_k = a vector of commuting modes, say, VHC2~VHC4 (VHC1, walking, is the default)

$DWTYPE_k$ = a vector of housing types, including DWTYPE1, DWTYPE2, DWTYPE3 (DWTYPE4, privately rental housing, is the default.)

Z_k = a vector of work zone specific dummy variables (Zone 1 is the default).

Our main purpose in this equation is to get the dummy coefficients for Z_k . These coefficients give the commuting time differences between each zone and the first zone, namely, the pure locational commuting times across those work zones, after controlling for all the other independent variables. In addition, we can also examine how individual household characteristics, commuting mode and housing type affect commuting pattern. We emphasize housing type here as a factor correlated with commuting pattern because many of these housing units not only could not be freely transacted on the market, but also they have specific location patterns in the urban area.

Secondly, we follow Timothy and Wheaton (2001) to estimate a semi-log wage equation also incorporating work zone dummies (Equation (3)). Only individual characteristics and zone dummies are included on the right side.

$$\ln(\overline{INCT}_k) = c + \omega' X_k + \lambda' Z_k, \quad k = 1, \dots, K \quad (3)$$

In this equation, the dummy coefficients for $Z_k(\lambda)$ show the pure locational income levels across different zones, with the first zone's income level being normalized to zero. In addition, this permanent income equation also gives us an opportunity to examine the contributions of various human capital factors to wages in Chinese cities nowadays when the labor market has been largely liberated.

From the empirical estimations of Equation (2) and (3), an identical worker's commuting times ($IDCOMT$) and incomes ($IDINCT$) in each work zone can be calculated by assigning specific values to this identical worker's characteristics. Our main interest lies in these two series— how the incomes and commuting times for this identical worker differ according to the zone in which where he/she works. If the hypothesis of commuting cost capitalization into wages holds, these two series (each one has 41 observations) should be positively correlated.

(3) Log-linear wage equation with identical worker's commuting time

Another approach to test this argument is to directly incorporate the identical worker's commuting time in each zone as an additional independent variable in the income equation, as a replacement for the work zone dummies (Equation (4)).

$$\ln(INCT_{jk}) = c + \omega' X_{jk} + \rho IDCOMT_j, \quad k = 1, \dots, K; \quad j = 1, \dots, J \quad (4)$$

Where,

j is the zone ID;

$IDCOMT_j$ is the identical worker's commuting time in work zone j (not the individual k 's own commuting time).

The reason why we do not instead use the individual's commuting time as the independent variable is that urban theory links individual wages to the zonal commuting time.

The coefficient before $IDCOMT$ represents the semi-elasticity of wages with respect to that identical worker's commuting costs in individual k 's work zone. In our empirical work household income is employed. If household income bears a constant relationship to the individual's wage, it will not influence the estimation of this elasticity.

The magnitude of wage elasticity with respect to commuting costs shows the value of travel time for workers. Timothy and Wheaton's result (2001) shows it is 0.008 for Boston and 0.012 for Minneapolis, indicating that the value of travel time ranges from 1.6 to 3.0 times the wage rate. They explain that wage rate variation necessary to compensate workers for added commuting should incorporate not only the time, but also the direct money expenses associated with that additional commute. According to Small (1992) such costs, e.g., gasoline, parking, auto maintenance, and depreciation, are always at least the magnitude of the time cost.

(4) Zonal wage level and agglomeration effect

If the commuting cost capitalization argument holds true for Beijing, then job decentralization would be a good thing --. Decentralization should lead to lower firm labor costs, which will lead to higher productivity.

Here another question arises: if locating far away from its workers results in higher labor cost, why would the firm choose to do so? Current urban theories suggest that firms locate further away from workers in order to enjoy the benefits from agglomeration economies. Urban economic theories have pointed out that economies of agglomeration prevent firms from becoming fully dispersed to eliminate commuting. Firms always make a trade-off between agglomeration benefits and labor costs, with the former encouraging them to be more clustered with each other to enjoy the face-to-face communication and knowledge spillover, and stimulate innovation, while the labor cost consideration pushes them to be more dispersed to follow where their workers live.

We also tentatively investigate whether some measures of agglomeration can explain some variations in wage and commuting cost. The number of workers in each zone (NJOB), the ratio of jobs to houses in

each zone (JHR), and a “mix” measure (MIX) are employed to represent agglomeration effects. The variable of MIX is calculated as below (Equation (5)). It represent how easy it is for firms in one zone to attract workers from its own zone and other nearby zones. The bigger MIX is, the easier it is for firms in the given zone to have access to their labor force. Alternatively, MIX may indicate less agglomeration.

$$MIX_i = \sum_{j=1}^J \frac{1}{\exp(D_{ij})} \cdot N_{ij} / NJOB_i \tag{5}$$

Where,

$i, j = 1, \dots, J$ the ID of zones;

N_{ij} = the number of workers who work in zone i and live in zone j ;

$NJOB_i$ = total number of workers who work in zone i .

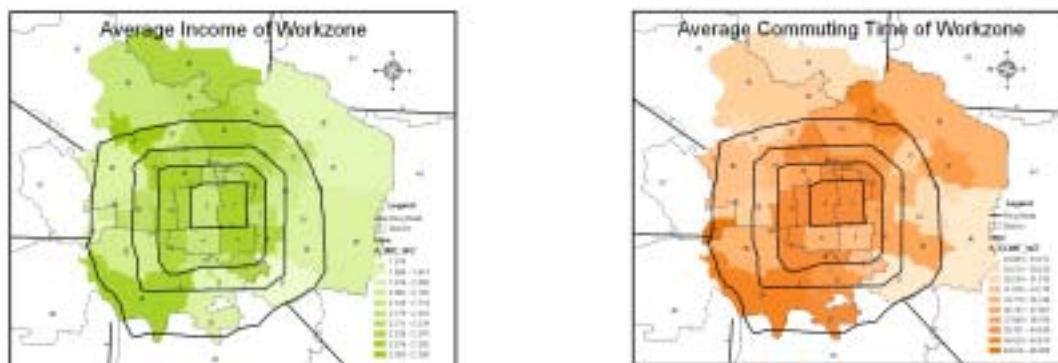
D_{ij} = distance between zone i and zone j .

Empirical Results

(1) Zonal average wages and commuting times: strongly and positively correlated

Average incomes and commuting times in the 42 zones are calculated and shown in Graph 2.

Figure 2. AVERAGE INCOMES AND COMMUTING TIMES IN 42 ZONES



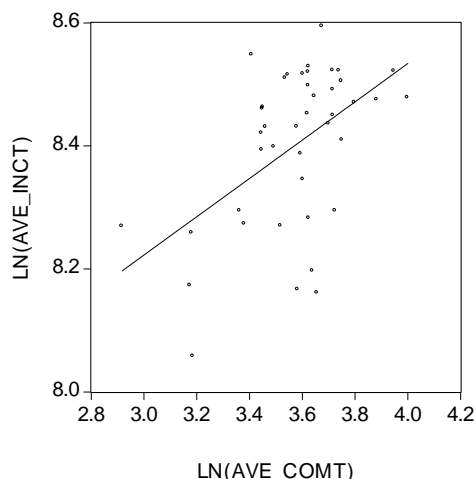
The simple regression of average income on average commuting time in log-log form is shown in Figure. 1 and Table 4.

Figure 1. LN(AVE_INCT) VS. LN(AVE_COMT)

Table 4. REGRESSION OF AVERAGE INCOMES ON AVERAGE COMMUTING TIMES IN 42 ZONES

Dependent Variable: LOG(AVEINCT)	
Variable	Coefficient (t-stat.)
C	7.289*** (24.342)
LOG(AVECOMT_W)	0.311*** (3.722)
Adjusted R-squared	0.239
F-statistic	13.854***
Obs.	42

Note: ***: significant at 1% level.



We can see that these two variables are strongly and positively correlated. The zones with average longer commuting times do have higher wage levels, and this simple defined equation can explain 23.9% of the zonal income variation across space. It seems that the compensation argument still holds in Beijing, but we need to remember that self-selection bias may exist in this result. To get more rigorous results, we turn to a commuting time equation and an income equation to control for individual heterogeneities.

(2) Identical worker’s wages and commuting times across work zones: also positively correlated

Table 5 and 6 show the estimation results of equation (2) and (3). The commuting time equation has an adjusted-R2 as 0.427. The most significant variables are commuting modes and housing types. Consistent with Table (2), workers using public transit have the longest commuting time, followed by private transportation, bicycle and walking. Tenants have shorter travel time than homeowners, due to more flexibility in changing home locations according to job changes, so they have higher probability to stay in locational equilibrium. Residents in newly-built economy-housing have the longest average travel time, consistent with the fact that most of the subsidized land parcels assigned for such projects are located at the periphery of the city. But employment has not been decentralized that much, forcing residents to travel a long way inward to their workplaces. The favorable location of work-unit housing apparently brings transportation benefits to their residents reflected in the significantly shorter commuting time.

Table 5. COMMUTING TIME EQUATION WITH ZONE DUMMIES

Dependent Variable: Ln(COMT)	
Variable	Coefficient (t-stat.)
C	2.574*** (17.916)
GENDER	-0.009 (-0.516)
AGE	-0.005 (-0.494)
HHSIZE	-0.012 (-1.216)
Ln(INCT)	-0.035** (-2.041)
EDU	0.024* (1.686)
OCCUP2	0.006 (0.257)
OCCUP3	0.019 (0.697)

Table 6. INCOME EQUATION WITH ZONE DUMMIES

Dependent Variable: Ln(INCT)	
Variable	Coefficient (t-stat.)
C	7.029*** (95.009)
GENDER	0.048*** (3.040)
AGE	0.142*** (3.338)
AGE ²	-0.032*** (-3.548)
HHSIZE	0.328*** (9.625)
HHSIZE ²	-0.037*** (-5.862)
EDU	0.263*** (20.560)
OCCUP2	0.076*** (3.292)

OCCUP4	0.056* (1.699)	OCCUP3	-0.080*** (-3.153)
OCCUP5	0.002 (0.056)	OCCUP4	-0.072** (-2.371)
VHC2	0.754*** (24.041)	OCCUP5	-0.027 (-0.993)
VHC3	1.371*** (47.767)	And 41 work zone dummies	
VHC4	1.034*** (29.328)	<hr/>	
DWTYPE1	0.084*** (2.819)	Adjusted R-squared	0.190
DWTYPE2	0.224*** (6.248)	F-statistic	20.951
DWTYPE3	0.138*** (4.209)	Obs.	4345
<hr/>		<hr/>	
And 41 work zone dummies			
Adjusted R-squared	0.427		
F-statistic	58.315		
Obs.	4306		

Higher-income workers have shorter commuting time, even after controlling for transportation mode. This represents an urban form more similar to European cities than to American cities (see, e.g., Brueckner, Thisse and Zenou, 1999). The relative centralization of the high-income residents in Chinese cities is probably due to the concentration of high-paying jobs and cultural and consumer amenities. Higher-educated workers have slightly longer commuting times. This result may be attributed to the thinner labor market for them—they need to travel further to find suitable positions.

The income equation has signs mostly accordant with our expectations. Male workers earn more. Worker's age has quadric effect on income with the peak for workers 30~45 years old, mainly reflecting the intersection of old planned economy-oriented and new market-oriented wage systems. Highly-educated workers earn significantly higher wages, indicating human capital has really played an important role here.

An identical worker is defined as below (Table 6). Basing on this definition, his incomes and commuting times across 42 zones are calculated. Simple regression of identical worker's income on his commuting time is run to examine their correlation, as showed in Table 7.

TABLE 6 DEFINITION OF IDENTICAL WORKER

Variable	Value
GENDER	1 (male)
AGE	2 (30~39 years old)
HHSIZE	3 persons per household
EDU	3 (undergraduate)
OCCUP	OCCUP2=1, others=0 (professional)
DWTYPE	DWTYPE3=1, others=0 (commodity housing)
VHC	VHC3=1, others=0 (public transit)

TABLE 7 REGRESSION OF IDENTICAL WORKER'S INCOMES ON COMMUTING TIMES IN 42 ZONES

Dependent Variable: LOG(IDINCT)	
Variable	Coefficient (t-stat.)
C	1.087 (1.435)
LOG(IDCMT)	0.403** (2.083)
Adjusted R-squared	0.100
F-statistic	4.339**
Obs.	42

Note: **: significant at 5% level.

INCT	4,000
(in commuting time equation)	

Adjusted R2 and F-statistic becomes smaller after controlling for individual characteristics, showing that systematic variation of these variables across space really contributes to the high correlation of average zonal commuting time and income level. But significant and positive correlation between these two still exists, confirming the wage’s “purely” locational compensation for commuting cost.

(3) The elasticity of wages with respect to zonal commuting times: value of travel time

Equation (4) gives us another way to test the compensation argument, and also the value of travel time can be directly derived from the coefficient before IDCOMT. We can take advantage of the large number of observations from this individual-level equation to get more robust results. Regression results are listed in Table 8.

Table 8. TRAVEL TIME COEFFICIENT IN INCOME EQUATION

Dependent Variable: LOG(INCOMET)	
Variable	Coefficient (t-stat.)
C	6.586*** (60.044)
GENDER	0.052*** (3.275)
AGE	0.148*** (3.422)
AGE ²	-0.033*** (-3.586)
HHSIZE	0.334*** (9.342)
HHSIZE ²	-0.039*** (-5.733)
EDU	0.264*** (20.486)
OCCUP2	0.073*** (3.239)
OCCUP3	-0.078*** (-3.097)
OCCUP4	-0.072** (-2.413)
OCCUP5	-0.028 (-0.992)
IDCOMT	0.0089*** (4.052)
Adjusted R-squared	0.184
F-statistic	90.120***
Obs.	4345

Note:
 ***: significant at 1% level;
 **: significant at 5% level
 White Heteroskedasticity-Consistent Standard Errors & Covariance is used.

Table 9. TRAVEL TIME COEFFICIENT IN INCOME EQUATION WITH HOME ZONE DUMMIES

Dependent Variable: LOG(INCOMET)	
Variable	Coefficient (t-stat.)
C	6.584*** (56.546)
GENDER	0.044*** (2.796)
AGE	0.141*** (3.257)
AGE ²	-0.031*** (-3.431)
HHSIZE	0.324*** (9.010)
HHSIZE ²	-0.037*** (-0.037)
EDU	0.261*** (0.261)
OCCUP2	0.078*** (0.078)
OCCUP3	-0.072*** (-0.072)
OCCUP4	-0.064** (-2.117)
OCCUP5	-0.027 (-0.950)
IDCOMT	0.0095*** (4.156)
And 41 home zone dummies	
Adjusted R-squared	0.198
F-statistic	21.609***
Obs.	4345

Note:
 ***: significant at 1% level;
 **: significant at 5% level
 White Heteroskedasticity-Consistent Standard Errors & Covariance is used.

The coefficient on IDCOMT is significant and has a magnitude of 0.0089, representing the semi-elasticity of the wage with respect to two additional minutes (2/480 of the time spent working in an 8 hour day) of commuting time (since commuting times are reported as one-way). Dividing the estimated coefficient by

this fraction gives a value of commuting cost that is 2.13 times the wage rate. If we consider time cost and also out-of-pocket cost related to traveling, this number is quite in line with the estimation that direct money expenses of commuting is at least the magnitude of the time cost (Small, 1992). Furthermore, this coefficient is quite close to those of Boston (0.0079) and Minneapolis (0.0120) found by Timothy and Wheaton (2001). Therefore, after twenty years' urban spatial structure transformation along with the overall economic reform process, intra-urban commuting cost differentials have been well capitalized into wages in the Beijing metropolitan area, showing the strong market forces at work as Beijing moves toward a more mature spatial labor market.

An alternative explanation of this effect may be that some omitted variable related to individual ability (and hence wages) is spatially correlated as well as correlated with commuting costs. For instance, some omitted measure of individual ability may be the cause of spatial segregation—high ability workers tend to commute further either for a good job or a nice house. To control for this, home zone dummies are added into Equation (4) (Table 9). Also, in theory, after controlling for where workers live, those who commute farther should get paid more. The coefficient on IDCOMT in Table 9 again confirms this, and actually it becomes more significant comparing to that in Table 8, indicating that omitted variables should not be a problem creating bias in the results.

We also try to figure out whether this compensation is consistent across different worker groups. We do so by adding some interaction dummy variables into Equation (4). Table 10 shows the regression results.

Coefficients for some worker groups simply represent their different time value, e.g., those coefficients before age and occupation types. However, though female workers have lower value of time (indicated in Table (6)), they can get higher compensation for their traveling, showing that women value their time lost to commuting more than men do, possibly due to traditionally having a greater share in household responsibilities. By comparison, it is not significant that highly-educated workers with high value of time can get extra commuting cost compensation from wages (after controlling for where they live). We are not sure about the exact reason for this. It may be attributed to the fact that working overtime is very common for high-skilled professionals in large cities, so it is hard to derive their value of time from their wage level.

Workers living in different housing types enjoy quite different commuting cost compensations. To closely examine if this is in line with the value of time, Table 11 puts together the corresponding coefficients into the commuting time equation and income equation. These coefficients do not show casual relationships, but only demonstrate differences among housing types.

Table 10. TRAVEL TIME COEFFICIENTS FOR DIFFERENT WORKER GROUPS

Dependent Variable: LOG(INCOMET)			
Variable	Coefficient (t-stat.)	Variable	Coefficient (t-stat.)
Same individual variables as Table (8) and (9)		IDCOMT×(OCCUP4) Service workers	0.0135* (1.733)
IDCOMT	0.0030 (0.543)	IDCOMT×(OCCUP5) Self-employed workers	-0.0012 (-0.170)
IDCOMT×(EDU>2) Highly-educated	0.0012 (1.458)	IDCOMT×(DWTYP1) Work-unit housing	0.0016** (2.512)
IDCOMT×(1-GENDER) Female	0.0090** (2.090)	IDCOMT×(DWTYP2) Economy-housing	0.0046*** (6.183)
IDCOMT×(AGE=2) 30~39 years old	0.0018*** (3.271)	IDCOMT×(DWTYP3) Commodity housing	0.0063*** (9.171)
IDCOMT×(OCCUP2) Professionals	0.0032 (0.501)	41 home zone dummies	
IDCOMT×(OCCUP3) Industrial workers	-0.0110* (-1.704)		
Adjusted R-squared	0.229		
F-statistic	21.778***		
Obs.	4345		

Note: ***: significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Table 11. WAGE COMPENSATIONS ON COMMUTING TIMES FOR WORKERS LIVING IN DIFFERENT HOUSING TYPES

Housing type	Coefficient in	Coefficient in	Coefficient in income eq. with
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	commuting eq. with work zone dummies (t-stat.)	income eq. with work zone dummies (t-stat.)	IDCOMT and interaction terms (t-stat.)
Work-unit housing	0.084*** (2.819)	0.093** (2.117)	0.0016** (2.512)
Economy-housing	0.224*** (6.248)	0.320*** (6.148)	0.0046*** (6.183)
Commodity housing	0.138*** (4.209)	0.430*** (9.030)	0.0063*** (9.171)

Note: privately rental housing is the default category. ***: significant at 1% level.

We find that workers in different housing types get commuting cost compensation largely in line with their values of time. Workers in newly built commodity housing always have high income levels, as well as the compensation for traveling they receive. For those who live in work-unit housing, most of them still work in nearby work units that provided and later sold the dwellings to them. They do not need to commute long ways, and at the same time they earn less (many of such work units are old firms or government bureaus) and receive less compensation. However, for workers in newly built economy-housing that is almost always located at the city fringe, the coefficient in commuting equation is about two times that of workers in commodity housing, but their compensation is really less than that of commodity housing residents. Although the travel time seems to be correctly priced into wages in the labor market, this may cause an affordability problem for people in economy-housing, but we still need housing price data to fully investigate this issue.

(4) Inconclusive evidence on agglomeration effect

Finally, we investigate whether firms are willing to pay higher compensation for their workers' commuting costs because they want to cluster together to enjoy the benefits of agglomeration economies. Three indicators, namely, NJOB, JHR and MIX, are calculated for each work zone and used to explain zonal commuting time and income. If agglomeration economies do play an important role, we should expect IDCOMT or IDINCT (AVECOMT or AVEINCT) to be positively correlated with NJOB or JHR, as well as negatively correlated with MIX. Table 12 gives the correlation matrix among these variables. It seems that wages and travel times are highly correlated with the aggregate number of workers in each zone. The correlation coefficients between MIX and those commuting and income variables are also in line with our hypothesis that those zones attracting workers who live in far away zones (lower MIX level) have higher zonal commuting times and wage levels. But the simple jobs-housing ratio without considering whether they are truly matched shows correlation results opposite to our expectation.

Table 12. CORRELATION MATRIX WITH AGGLOMERATION INDICATORS

	IDCOMT	IDINCT	AVECOMT	AVEINCT
NJOB	0.146	0.245	0.161	0.352
JHR	-0.019	-0.057	-0.043	-0.023
MIX	-0.251	-0.101	-0.204	-0.130

Note: 42 observations for each variable.

A disadvantage with these indicators is that they are all directly derived from this survey sample, so we cannot be sure that the above correlation relationships are truly causal, or just reveal some mechanics in the dataset. If further data on firm concentration or employment specialization can be obtained and used to describe spatial agglomeration patterns, more reliable conclusion may be drawn.

CONCLUSION AND FUTURE WORK

Until now no rigorous study has been done on intra-urban wage variation and commuting cost capitalization in China. The unique and transforming nature of Chinese cities makes it a worthy research topic to test the validity of this urban theory and expand our knowledge of urban spatial structure in China.

Our empirical study shows that workers' commuting cost differential has been well and consistently capitalized into wages in Beijing. On average, the cost of travel (time plus commuting cost) is about 2.1

times the wage rate (for that amount of time). This result is robust after controlling for where workers live. Workers with higher opportunity cost of time can always get higher compensation on their travel time. Therefore, as employment is still quite centralized despite of the fast suburbanization of residential land use there, decentralization of job opportunities can effectively save firms' labor cost and hence increase their productivity.

When we continue to investigate why firms tolerate such high wage premium to cluster together, we can not find conclusive evidence on agglomeration economies, at least using this survey data. Furthermore, we suspect that the historical path matters here: it still takes some time for the durable fixed investments in the foregone planned economy era to adjust to the new market economy. Other reliable data is needed to test this hypothesis. Good urban policies are essential to facilitate the adjustment process and improve the efficiency in Chinese cities' urban spatial structure.

Our future work is using some other geocoded datasets to further examine the causalities in Chinese cities' urban spatial structure. Currently the transaction database of newly-built housing projects in Beijing is also available to us, which can be employed to derive the spatial distribution of housing prices. In addition, population data in those 120 communities in Beijing urban area from 2000 census can also be used to get the information of population distribution. Combining these several databases together will produce many interesting urban stories.

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