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# **Urban Density, Human Capital, and Productivity: An empirical analysis using wage data**

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Urban Density, Human Capital, and Productivity:  
An empirical analysis using wage data\*

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Abstract

Numerous studies have indicated that densely populated cities enhance the productivity of workers through knowledge spillover and superior matching with employers in the labor market. This paper quantitatively analyzes the relationship among urban density, human capital, and wages by using micro data from the *Basic Survey on Wage Structure* for the years from 1990 to 2009. According to the estimation of standard wage functions augmented with population density, the agglomeration premium is larger for workers with higher observable skills such as education, tenure, and potential experience, which suggests rapid learning and superior matching in densely populated cities. Under structural changes such as a declining population and the trend toward a knowledge-based service economy, forming densely populated areas by facilitating the migration of workers has desirable effects throughout Japan on both individual wages and firm productivity.

*Keywords:* agglomeration, population density, human capital, and wage function.

*JEL Classification:* J24; J31; R32

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## 1. Introduction

This paper empirically analyzes the relationship among urban density, human capital, and wages by using individual micro data on wages in Japan.

Faced with an aging population and a decreasing labor force, Japan must now focus its economic policy on enhancing productivity to achieve sustainable economic growth. It is a well-known fact that accumulation of human capital is an important contributor toward productivity growth.<sup>1</sup> Investments in human capital include not only formal education through schooling but also skill accumulation through employer-provided training programs and on-the-job learning. Recent empirical studies, surveyed in the next section, have pointed out that the contribution of human capital toward worker productivity is related to the economies of agglomeration. Human capital spillover, learning through experience, superior matching in the labor market, and the sorting of workforce based on ability are pointed out as the theoretical mechanisms behind the facts.

The population in Japan is projected to decrease rapidly. If the contribution of human capital toward productivity is stronger in large, densely populated cities, spatial redistribution of population through internal migration may have an impact on Japan's economic growth. Under a trend toward a knowledge-based economy, investment in and utilization of human capital is becoming increasingly important. Fujita (2007), for example, argues that the optimal city size will become larger in parallel with the heterogeneity of knowledge that is more important in the knowledge production process.

Against this background, this paper empirically analyzes the interconnection between human capital and population density in determining wages using data from the *Basic Survey on Wage Structure*. Specifically, we estimate wage elasticity to density for different observable skill groups to deepen our understanding on the heterogeneous effects of agglomeration. Notably, by comparing a "standard worker," who has not changed employers after graduation, with a "non-standard worker," who has changed jobs, we attempt to disentangle the channels causing the agglomeration wage premium, such as learning through experience in dense cities and superior matching between employer and employee.

As explained in the next section, the endogenous quality of labor is one of the possible sources of bias in the estimation for agglomeration economies. That is, workers with superior unobservable human capital may sort into denser and more productive regions. Recent

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<sup>1</sup> There have been numerous studies on the relationship between human capital and economic growth or productivity. Topel (1999), Blundell et al. (1999), Krueger and Lindahl (2001), and Hanushek and Woessmann (2008) present good surveys on education and economic growth.

empirical studies have made efforts to remove this bias by using individual-level panel dataset. Unfortunately, a large panel dataset that tracks individual workers is unavailable in Japan. As a result, a limitation to this paper is that the analysis is of a cross-sectional nature. However, according to empirical studies tackling workforce sorting issues, the magnitude of the endogeneity bias cannot be ignored as there still remain economically significant agglomeration economies, even after correcting this bias.

The major results of the analysis in this paper can be summarized as follows.

- (1) Simple elasticity of nominal wages with respect to municipal population density is about 0.08. Even after controlling for individual worker characteristics, firm size, and regional price disparities, significant agglomeration (urban) wage premium is observed, although elasticity drops to about 0.03.
- (2) The urban wage premium is larger for university graduates. This suggests agglomeration economies and skills are complementary.
- (3) The urban wage premium increases with worker tenure, until around 20 years of tenure. The result suggests that human capital accumulation through learning by experience within a firm is relatively large in densely populated cities.
- (4) The urban wage premium increases with the potential experience of workers, until around 30 years of experience. This relationship is stronger for the non-standard worker who changed jobs than the standard worker who worked at a single firm for a long time. This result suggests that, in addition to learning effects, quality of matching between workers and firms through labor turnover is better in densely populated cities.

The remainder of this paper is structured as follows. Section 2 briefly reviews the literature on the relationship among agglomeration, productivity, and wages. Attention is paid to studies on the relationship between human capital and city size. Section 3 describes the data employed and the method of analysis. Section 4 reports the estimation results of the wage function. Section 5 presents conclusions with policy implications.

## 2. Literature Review

### 2.1 Urban Wage Premium

It is a stylized fact confirmed by numerous empirical studies that measured productivity is higher in spatial areas where economic activities are agglomerated (see Rosenthal and Strange, 2004; Combes, Mayer, and Thisse, 2008; Strange, 2009; Glaeser and Gottlieb, 2009; Puga, 2010). The measures of agglomeration used in these studies include population,

population density, worker density, and the number of establishments. The mechanisms behind this stylized fact have been considered to be economies of scale and positive externalities in production. The externalities arise from labor market pooling, input sharing, and knowledge spillovers. Rosenthal and Strange (2004), who conducted a representative survey in the area, conclude that productivity increases by 3%–8% when regional population density doubles. A meta-analysis by Melo et al. (2009) depicts that the mean and median of the estimated elasticity of productivity with respect to density are 0.031 and 0.034, respectively. <sup>2</sup>

Most of the previous studies estimate 1) production functions to derive the agglomeration effect on productivity or 2) wage functions to find the agglomeration premium on factor prices. The analysis in this paper belongs to the latter category. Representative studies adopting this approach include Glaeser and Mare (2001), Wheaton and Lewis (2002), and Yankow (2006) for the U.S., Combes, Duranton, and Gobillon (2008) for France, and Mion and Paolo (2009) for Italy.

When estimating wage function to analyze agglomeration wage premium the potentially major sources of bias are 1) endogeneity of population and 2) endogeneity of the quality of workforce i.e., worker sorting. Recent empirical studies referred to these efforts to overcome the endogeneity issues. Notably, several studies estimates wage functions and controlled for worker-fixed effects by using individual-level panel data. Glaeser and Mare (2001) utilized individual-level panel data for the U.S. and found that controlling for observable worker characteristics and individual fixed-effects considerably reduced the urban wage premium, but that a substantial urban wage premium still existed, which was not the result of omitted ability biases. Yankow (2006) conducted a fixed-effects estimation for U.S. panel data (NLSY79) and found that two-thirds of the urban wage premium could be explained by cities attracting workers of higher unmeasured skills and ability, and that the remaining urban wage premium consisted of both a wage level effect and a wage growth effect. Combes, Duranton, and Gobillon (2008) estimated a wage determination model across local labor markets using a large panel of French workers and control for worker characteristics, worker fixed effects, industry fixed effects, and the characteristics of the local labor market. According to their analysis, skilled workers tended to sort into larger and denser local labor markets, and differences in the skill composition of the labor force accounted for 40%–50% of aggregate spatial wage disparities. Combes, Duranton, Gobillon, and Roux (2010) analyzed the agglomeration wage premium by employing an instrumental variable approach to deal with the endogenous quantity of labor bias and a worker fixed-effect approach to deal with the endogenous quality of labor bias. Their results show that the raw elasticity of mean wages to density is slightly below 5%,

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<sup>2</sup> Most of the studies focus on manufacturing, but Morikawa (2011) found that the productivity effect of agglomeration is substantially larger for service industries than for manufacturing.

but the figure dropped to 2.7% after controlling for both endogenous quality and quantity biases. Mion and Paolo (2009) estimated a wage function using a matched employer-employee panel data for Italy and found that skills were sorted across space and accounted for nearly 75% of the spatial wage variation. Krashinsky (2011) conducted a unique study that examined the selection effects on measured agglomeration wage premium by using datasets of identical twins and siblings in the U.S. to control family fixed effects. He found large and significant effects of unobserved ability for agglomeration wage premium.

On the other hand, Fu and Ross (2010), who use residential location as a proxy for worker's unobserved productivity, found that the agglomeration estimates are robust to comparisons within residential locations, suggesting that the productivity differences across locations are due to agglomeration rather than productivity differences across individuals. Baum-Snow and Pavan (2011) decomposed the U.S. urban wage premium into various components such as latent ability, search frictions, firm-worker match quality, human capital accumulation, and endogenous migration, and conducted counterfactual simulations. Their simulations depict that sorting on the basis of unobserved ability contributes little to these observed urban wage premium.

To summarize, although the biases from endogenous quantity and endogenous quality of labor cannot be ignored, there remains a quantitatively significant agglomeration wage premium. Strange (2009), who conducted a survey on recent research on agglomeration economies, states "we have strong evidence of endogenous quality of labor, but also strong evidence for a relationship between urbanization and a wage correcting for this." Combes, Duranton, and Gobillon (2011), who reviewed empirical studies on the elasticity of wages with respect to urban scale focusing on various estimation biases and econometric solutions, concluded that standard estimates for the density elasticity of wages now typically range from 0.02 to 0.05. They then argue that while better estimates are needed, it is also important to explore what lies behind the "average" values and that knowing more about how different types of workers and firms benefit from agglomeration is of first order importance. The present paper follows this line of research.

## 2.2 Human Capital and Agglomeration Economies

There are many possible mechanisms behind the high productivity of workers in densely populated cities. In addition to the establishment-level factors, such as scale economies and technological differences, labor market factors including rapid human capital accumulation and superior matching of employers and employees are also important.

The relationship between human capital and wages has been a major research topic in labor economics and has had an extensive history. Certain recent studies on the urban wage premium focus on the different agglomeration effects of observable skills of workers, such as education and tenure. Glaeser and Mare (2001), Wheeler (2001, 2006), Gould (2007), Di Addario and Patacchini (2008), Chung et al. (2009), Bacolod et al. (2009), and Christoffersen and Sarkissian (2009) are examples of this line of research.

Glaeser and Mare (2001), as previously referred to, indicate that a significant fraction of the urban wage premium is accumulated with workers' experience in the urban labor market. Wheeler (2001) depicts evidence for the U.S. that wages of highly educated workers rises significantly compared with less educated workers as local population increases. Wheeler (2006), by analyzing U.S. panel data (NLSY79), found that wage growth is positively associated with local market size, and that this association is the product of rapid wage growth from job changes rather than from wage increases experienced while on a particular job. Based on the results, he concludes that cities enhance worker productivity through a job search and matching process. Gould (2007) analyzes the relationship between wages and city size for both blue-collar and white-collar workers by estimating a structural model for the U.S. The results indicate that the selection of individuals into occupations and locations can almost explain the urban wage premium for blue-collar workers, but explains only a third of the regional wage gap for white-collar workers. Moreover, he concludes that cities make white-collar workers more productive. Chung, Clark, and Kim (2009), using cross-sectional data for the U.S., indicate that virtually all skill wage premium growth over the 1980s in the U.S. was confined to metropolitans. They offered the possible explanation that skilled workers may decrease the cost of acquiring knowledge and facilitating communication for urban employers more effectively than non-urban ones. Bacolod et al. (2009), making use of the Dictionary of Occupational Titles (DOT) and data from the U.S. census and the NLSY, estimate the impact of agglomeration on the hedonic prices of worker skills. According to their analysis, the urban wage premium is greater for workers with high cognitive and people skills, but not for workers with high motor skills. Specifically, an increase of one standard deviation from the mean in cognitive skills increases wage elasticity with respect to the MSA population by one-fifth. Christoffersen and Sarkissian (2009) analyzed the relationship between city size and the performance of U.S. equity mutual funds and found that funds in financial centers perform better than other funds. Interestingly, this difference is driven only by more experienced managers, and there is strong evidence of a positive relationship between performance and manager experience among funds in financial centers such as New York. They argue that the

result is evidence of knowledge spillover and learning in cities.<sup>3</sup>

To summarize, most empirical studies in the U.S. and other advanced countries found that the effects of worker skills such as education and experience on wages are greater in populated cities. These studies suggest that density enhances worker productivity through rapid accumulation of human capital and superior matching between employers and employees.

Based on these previous studies, this paper empirically analyzes the relationship between wage premium for various observable skills—education, tenure, and potential experience—and population density in Japan. Special attention is paid to different agglomeration wage effects between standard workers i.e., lifelong employees and non-standard workers who experienced job changes.

### 3. Data and Methodology

This paper uses individual-level micro data from the *Basic Survey on Wage Structure* (Ministry of Health, Labour and Welfare). To link the data with published population census data; we used data for the years 1990, 1995, 2000, 2005, and 2009, which is the latest available data.

The survey is the most frequently utilized source of official statistics on estimating wage functions. The objective of the survey is to clarify the wage structure of employees in major industries by type of employment, work, occupation, sex, age, education, length of tenure, occupational career, and other factors. Since 1948 the survey has been carried out once a year. Approximately 80,000 establishments were sampled according to a fixed ratio by region, industry, and size of establishment. In addition, a number of workers from among those employed in the sampled establishments were chosen according to a fixed ratio by industry and size of establishment. The items surveyed include; actual numbers of scheduled hours worked, actual number of overtime worked, contractual cash earnings, scheduled cash earnings, annual special cash earnings (bonus), industry, size of enterprise, sex, age, tenure (length of service), and education. The number of workers surveyed is about 1.2 million, of which 1.0 million are full-time regular workers. Since data on education are unavailable for part-time workers, analysis in this paper is conducted only on full-time regular workers.

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<sup>3</sup> In contrast to these studies, Di Addario and Patacchini (2008), by using data for Italy, found that urban scale does not affect returns to experience and that it reduces returns to education and tenure with the current firm.



The standard worker is a special notion of the survey, and is defined as “a worker who joined a firm just after graduation and served the firm continuously.” More specifically, standard workers are identified as workers whose age minus tenure equals 15 years for junior high school graduates, 18 years for senior high school graduates, 20 years for junior college or technical college graduates, and 22 or 23 years for university graduates. This paper estimates wage functions separately for standard and non-standard workers when necessary. The number of standard workers in the sample is about 300,000 or roughly 30% of the number of full-time regular workers (see Table 1).

Survey items utilized in this paper include prefecture and city code, industry classification, worker characteristics (sex, type of employment, type of work, education, age, and tenure), working hours, and wages. Among these, type of employment is classified into 1) regular worker and 2) non-regular worker, and type of work is classified into 1) full-time work and 2) part-time work.<sup>4</sup>

During the last decade, the Standard Industry Classification has been revised fundamentally. In the 2005 survey, several new single-digit industries, such as “information and communications,” “medical, health care and welfare,” “education and learning support,” and “compound services” were established, and “restaurants” were separated from the category of “wholesale, retail, and restaurants.” Furthermore, in the 2009 survey “goods rental,” formerly a part of “professional and technical services,” was reclassified into “real estate, goods rental, and leasing.” Thus, we construct a single-digit industry classification harmonized from 1990 to 2009. Concretely, we classified 11 industries: mining, construction, manufacturing, electricity and gas, transportation and communication, wholesale, retail, restaurants, finance and insurance, real estate, and services.

In this study, monthly wage is calculated as the sum of monthly contractual cash earnings (including overtime allowance) and annual special cash earnings (bonus) divided by twelve. Hourly wage rate (hundred yen per hour) is the monthly wage divided by the actual number of hours worked. In estimating wage functions, the natural log of hourly wage rate is used. Potential experience of workers is calculated by subtracting normal graduation age (15 for junior high school graduates, 18 for senior high school graduates, 20 for junior collage or technical collage graduates, and 22 for university graduates) from current age.

City-level data on population, area, and price level are merged with the above mentioned individual-level data to construct the final dataset. Population and area data at the city level are taken from the website of the Statistical Bureau of the Ministry of Internal Affairs and

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<sup>4</sup> In 2005, the classification of the type of employment was altered and, as a result, employees are now classified into “regular staff for an indefinite period,” “regular staff for a definite period,” “non-regular staff for an indefinite period,” “non-regular staff for a definite period,” and “temporary employees.”

Communications.<sup>5</sup> The Index of Regional Prices for all households from the National Survey of Prices is used to construct regional price data, which is implemented to calculate real wages.<sup>6</sup> These statistics cover all cities with a population of more than 1000; however, unfortunately, cities with population below 100,000 were sampled, and sampling rates were from 12.5% to 50% depending on city size. As a result, the sample size becomes relatively small for the estimations using real wages as a dependent variable. Since the National Survey of Prices has been conducted every five years (1997, 2002, and 2007) and the years do not coincide with the years of the population census. We used price data for 2007 when calculating real wages for 2005 and 2009, and price data for 2002 when calculating real wages for 2000.<sup>7</sup> It should be noted that the effect of the two years' difference in the price data is minimal, as the price level in Japan was stable during the period of analysis.

The method of analysis in this paper is quite simple, including OLS estimates of standard wage functions, where the dependent variable is the log hourly wage rate (*lnwage*) and population density at the city level (*lnpopdens*) was a main explanatory variable.<sup>8</sup> Ordinary individual characteristics—sex (female dummy: *female*), potential experience (*potexp*) and its square (*potexpsq*), tenure (*tenure*) and its square (*tenuresq*), education dummies—and single-digit industry dummies are also used. Education is used as a dummy variable for junior collage or technical collage graduates (*edudum\_c*) and for university graduates (*edudum\_u*). In short, the equation to be estimated can be expressed as follows:

$$\begin{aligned} \lnwage = & \beta_0 + \beta_1 \text{ female dummy} + \beta_2 \text{ potexp} + \beta_3 \text{ potexp}^2 + \beta_4 \text{ tenure} + \beta_5 \text{ tenure}^2 \\ & + \beta_6 \text{ education dummies} + \beta_7 \text{ lnpopdens} + \beta_i \sum \text{industry dummies} + \varepsilon \end{aligned}$$

When pooled data was used in the estimation, year dummies for 1990, 1995, 2000, and 2005 were added. In the baseline estimation, we do not include firm size as an explanatory variable, but for certain specifications firm size dummies are added to check the robustness

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<sup>5</sup> Data on city population from 1990 to 2005 were taken from the population census. Population data for the year 2009 came from the Basic Resident Registers (Statistics Bureau, Ministry of Internal Affairs and Communications).

<sup>6</sup> Specifically, the city-level price index is calculated as the price index of prefectures (national average = 100) multiplied by the price index of cities (prefecture average = 100).

<sup>7</sup> Since detailed regional price data was not available before 1997, the analysis for real wages is restricted to the years 2000, 2005, and 2009.

<sup>8</sup> Instead of simple population density, we use worker density (the number of workers divided by the area) as the explanatory variable for the year 2005, where data on the number of workers by municipalities were available. The results are qualitatively and quantitatively quite similar to the results using simple population density.

of the results.<sup>9</sup>

When estimating the wage function for standard workers who joined a firm just after graduating from school and served the firm continuously, tenure and its square are excluded from the explanatory variable because potential experience and tenure are the same by definition.

In addition to the baseline equation written above, population density interacted with education, potential experience, or tenure is added to analyze the different effects of human capital on wages by urban density.

Summary statistics of the major variables for the sample of full-time regular workers are indicated in Table 2.

## 4. Results

### 4.1 Baseline Estimation

Table 3 depicts the estimation results for all full-time regular workers. Columns (1) and (2) are for the year 2009 and columns (3) and (4) are the results of pooling five years, from 1990 to 2009. Results for the years 1990, 1995, 2000, and 2005 are not reported here to avoid redundancy, but the results are essentially similar to that of the year 2009.

The raw wage elasticity with respect to population density without controlling for individual characteristics is between 0.08 and 0.09 (not reported in the table), but the figure drops to about 0.06 after controlling for sex, education, experience, and tenure (see Table 3, columns (1), (3)). This indicates that around a third of the observed regional wage disparity is explained by the different individual characteristics. The elasticity drops further to 0.04–0.05, when firm size dummies are added (columns (2), (4)). Although the effect of the inclusion of firm size on agglomeration wage premium is small, the results indicate that large firms tend to locate their establishments in populated regions, suggesting spatial sorting of firms.

Since price levels are generally higher in densely populated cities, the elasticity of real wages with respect to density is expected to be lower than that of nominal wages. Table 4 reports the results using log real wages as a dependent variable. The estimated elasticity is about 0.03–0.04, which indicates that about 2 percentage points of the measured nominal wage elasticity is accounted for by the fact that price levels are higher in denser cities. When using real wages, some of the small cities are excluded from the sample because of a lack of price

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<sup>9</sup> In the Survey, firm size is classified into eight categories based on the number of employees (5–9, 10–29, 30–99, 100–299, 300–499, 500–999, 1000–4999, 5000 or more).

data, and data for 1990 and 1995 were unavailable. Thus, in principle, we use nominal wages in the following analysis, but it should be remembered that the agglomeration wage premium in real terms adjusted by price level is lower by about 2 percentage points.

As explained in Section 2, when estimating the agglomeration wage premium, the bias caused by the endogenous selection (sorting) of workers is an important econometric issue. Although we unfortunately do not have panel data to control the possible sorting bias. To deal with this issue we restrict the sample to standard workers, who served a firm continuously after graduation. The estimation results are presented in Table 5. Even when the sample is restricted to standard workers, the sorting effect at the time of hiring cannot be eliminated, but the effects of selection through job changes are reduced.<sup>10</sup> The estimated wage elasticity to population density is close to 0.05 (Table 5 column (1)).

Even among standard workers, those in large firms with multiple establishments at various locations may be transferred among different locations during their career with the firm. In considering this possibility, we further limit the sample to 1) small- and medium-sized firms with total regular employees less than 300 (column (2)), and 2) single establishments in which a firm has only one establishment (column (3)). The estimated wage elasticity is quantitatively similar in magnitude to that obtained for all establishments.

#### 4.2 Agglomeration Wage Premium by Education

In this and the following subsections, we analyze the relationship between observable human capital and agglomeration wage effects. Specifically, we estimate wage functions including interaction terms of population density with education, potential experience, or tenure to investigate the different effects of human capital on wages by the degree of population density.

Table 6 reports the results for education. For junior college or technical college graduates, wage elasticity with density was not significantly different from that of high school graduates, but university graduates' wage elasticity was often large and significantly different from that of high school graduates. This suggests that workers with higher human capital benefit more from agglomeration, which is basically consistent with the results obtained in the U.S. (Wheeler, 2001; Chung, Clark, and Kim, 2009). The size of the coefficients for the interaction term for the year 2009 was about 0.01 (see Table 6, column (1), (2)), indicating that the wage premium of university graduates is about 1% larger when the local population density doubles. The size

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<sup>10</sup> As described in the text, potential experience and tenure is the same for standard workers by definition. We exclude tenure and its square from the explanatory variables in this estimation.

is only 0.003 for pooled regression results (see column (3) of the table), which is far smaller in magnitude compared with the coefficients for the university graduates dummy variable (around 0.3).<sup>11</sup> The coefficient for the interaction term is insignificant in the regression, including firm-size dummies.<sup>12</sup> In recent years, workers with higher education benefitted more from urban agglomeration, but the magnitude of this relationship is quantitatively limited.

#### 4.3 Agglomeration Wage Premium by Tenure

Next, we estimate wage functions where interaction terms for population density with tenure and its square are used as explanatory variables. Similar to the previous analysis, all of the observable worker characteristics are controlled. The coefficients for density interacted with tenure and its square are both highly significant, and the former is positive and the latter is negative (see Table 7). In this case, wage elasticity with density increases with tenure until 21 years of service and then decreases gradually. For example, the elasticity is about 0.05 at three years of tenure, but the figure grew closer to 0.07 at 20 years of tenure.

This result suggests that the rate of accumulation of human capital and productivity growth of workers are faster at establishments located in densely populated areas, suggesting a stronger on-the-job learning effect.

#### 4.4 Agglomeration Wage Premium by Potential Experience

The results of wage functions with the interaction terms of population density with potential experience and its square are reported in Table 8. Similar to the results of the previous subsection, the coefficients for the interaction terms are both statistically significant, and the signs are positive and negative. The peak of wage elasticity with density is about 30 to 31 years of potential experience, ten years later than the peak for tenure.<sup>13</sup> Figure 1 illustrates the experience-wage curve for hypothetical cities with different population densities. The upper

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<sup>11</sup> It should be noted, however, the standard deviation of the log population density is about 1.5 (see the summary statistics). One standard deviation for a denser city's wage premium for university graduates is 10% higher in the estimation for the year 2009.

<sup>12</sup> In considering the possibility that the form of the wage function may be different by educational groups, we conducted separate estimations by educational categories. The results are essentially similar to the results using the interaction terms described in the text. The wage elasticity with respect to population density is about 0.01 larger for university graduates.

<sup>13</sup> When interaction terms of both tenure and potential experience with population density ( $tenure * \ln popdens$ ,  $potexp * \ln popdens$ ) are used simultaneously in the equation, the size of the coefficient for the interaction term with potential experience was relatively large.

line represents the curve for a city with one standard deviation higher population density from the sample mean, and the lower curve represents a city with one standard deviation lower density.<sup>14</sup> The intercept depicts the effect of different population densities for workers hired just after their graduation, which can be interpreted as a sorting effect by unobservable skills at the time of hiring. The shape of the curve is steeper in a denser city and the magnitude is quantitatively larger. The result here is consistent with Glaeser and Mare (2001), which indicates that the coefficient for the interaction term for experience and city size is positive in the U.S.

The sample for the above analysis includes all full-time regular workers. We then divide the sample into standard workers and non-standard workers and run estimates separately. As mentioned already, in estimating wage functions for standard workers it is inappropriate to use potential experience and tenure at the same time; therefore, we drop tenure and its square from the explanatory variables. Table 9 displays the results for the pooling regression. Interestingly, the coefficient for the interaction term for experience and population density is larger for non-standard workers than for standard workers. Figure 2 illustrates the relationship between potential experience and density elasticity of wages for standard and non-standard workers. For standard workers, the peak elasticity is 0.058 at 25 years of experience and gradually decreases thereafter. On the other hand, for non-standard workers i.e., most of whom have experienced job changes, the peak elasticity is 0.080 at 30 years of experience; a roughly higher and later peak. The curve is relatively steep for non-standard workers, which indicates that the productivity enhancing effects of agglomeration becomes stronger for job-changers as work experience accumulates.<sup>15</sup> One plausible interpretation is that, after certain years of work experience, superior matching through job changes dominates the effects of on-the-job accumulation of skills. This is consistent with Wheeler (2006), who found that wage growth is positively associated with city size and that this association is the result of faster wage growth due to job changes rather than that experienced on a particular job. For example, the difference in the elasticities between standard and non-standard workers with 20 to 25 years of experience is about 0.02. This figure can be interpreted as an approximation of the effects of better matching. The different elasticities for standard workers at the time of hiring along with 20 to 25 years of experience (about 0.03) can be interpreted as an approximation of learning effects.<sup>16</sup>

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<sup>14</sup> The population density for a city with one standard deviation larger than the average is 5,871/km<sup>2</sup> and that of a city with one standard deviation lower is 287/km<sup>2</sup>.

<sup>15</sup> Some part of the effects of job changes should be interpreted as the effects of spatial sorting by skills and not the effects of better matching in large cities. This is because job changes include both intra-city and inter-city changes.

<sup>16</sup> Precisely, “passive sorting” cannot be ruled out because standard workers are the survivors who stayed with the firm they joined just after graduation.

Tables 10 and 11 report the results for the subsamples of 1) small- and medium-sized firms and 2) single establishments where the firm has only one establishment. For these subsamples, standard workers' transfer between different locations in their career is limited. Although the difference in the elasticities between standard and non-standard workers is somewhat smaller than the result using a total sample, the coefficients for the interaction terms for experience and density are still larger for non-standard workers, confirming the existence of superior matching effects in densely populated cities.

## 5. Conclusion

This paper empirically analyzes the relationship among urban density, human capital, and wages using Japanese micro data. Specifically, we estimate wage functions including population density as an explanatory variable by employing data from the *Basic Survey on Wage Structure* from 1990 to 2009. In particular, the estimations consider interaction terms between population density and various observable skills as well as comparisons between standard workers with lifetime employment and non-standard workers experiencing job changes. These estimations are conducted to disentangle the sources of agglomeration wage premium, such as learning through experience in densely populated regions, superior matching of employees, and employees in large labor markets.

The major results can be summarized as follows:

- (1) Simple raw elasticity of nominal wages with respect to municipal population density is about 0.08. After controlling for individual worker characteristics and firm size, this figure decreased to roughly 0.05. By further adjusting regional price disparities, the real wage elasticity becomes about 0.03. This figure is comparable with those found in previous studies.
- (2) The agglomeration wage premium is larger for university graduates. This suggests that agglomeration economies and worker skills are complementary.
- (3) The wage elasticity to density increases with the tenure of workers up to around 20 years. This result indicates that human capital accumulation through learning by experience within a firm is relatively large in establishments located in densely populated cities.
- (4) The wage elasticity to density also increases with the potential experience of workers up to around 30 years of experience. This relationship is stronger for “non-standard employees” who experienced job changes than “standard employees” who served at a single firm for long time. This result suggests that, in addition to the learning effects,

superior matching between workers and firms through labor turnover contribute to the urban wage premium.

These results highlight that working in an agglomerated region enhances worker productivity through both rapid learning and superior matching. Under structural changes such as a declining population and the trend toward a knowledge-based service economy, the results suggest that forming densely populated areas by facilitating inter-regional migration of workers have desirable effects on both individual wages and firm productivity throughout Japan. Although the effects of specific policies are beyond the scope of this paper, the creation of a well-functioning external labor market to enable flexible labor turnover, deregulation of land-use restrictions in urban areas, and efficient infrastructure investment focusing on populated areas may contribute to actualizing agglomeration economies.

The cross-sectional analysis in this paper is subjected limitations. The effects from the differences in unobservable skills among regions and spatial sorting of workers are not eliminated. However, it should be noted that, according to previous studies that employed panel data, even after correcting these biases, a significant agglomeration wage premium existed. The major purpose of this paper is not to measure accurately the size of the agglomeration economies, but to detect their difference among worker skills, although the quantitative magnitude of the wage premium found in this paper should be interpreted with discount.



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Table 1 Number of Sample Workers

	Regular worker	Full-time worker	Standard worker
1990	1,258,097	1,154,121	303,573
1995	1,382,724	1,239,455	397,673
2000	1,258,627	1,103,741	344,155
2005	1,187,773	946,249	253,918
2009	1,193,660	901,401	239,120
Average	1,256,176	1,068,993	307,688

Table 2 Summary Statistics

(1) 2009

	N	mean	sd	p50	max	min
lnwage	898,263	2.963	0.546	2.924	7.815	-2.549
female	901,401	0.318	0.466	0	1	0
edudum_c	901,401	0.145	0.352	0	1	0
edudum_u	901,401	0.294	0.456	0	1	0
age	901,401	41.010	12.359	40	99	15
potexp	901,401	21.699	12.939	21	79	0
tenure	901,401	11.768	10.839	8	66	0
lnpopdens	885,344	6.885	1.555	6.829	9.871	0.949
lnhours	898,263	5.132	0.193	5.147	6.178	0

(2) Pooling Five Years from 1990 to 2009

	N	mean	sd	p50	max	min
lnwage	5,327,834	2.969	0.556	2.944	8.679	-2.549
female	5,344,967	0.305	0.460	0	1	0
edudum_c	5,344,967	0.121	0.327	0	1	0
edudum_u	5,344,967	0.234	0.423	0	1	0
potexp	5,344,967	20.825	13.039	20	79	-1
tenure	5,344,967	11.892	10.447	9	66	0
lnpopdens	5,147,979	7.169	1.509	7.108	9.928	0.785
lnhours	5,327,834	5.175	0.191	5	6	0

Table 3 Estimation Results of Wage Functions

	(1)	(2)	(3)	(4)
	2009	2009	pooled	pooled
female	-0.2614 *** (-291.80)	-0.2654 *** (-309.96)	-0.2743 *** (-752.55)	-0.2783 *** (-803.99)
edudum_c	0.1348 *** (110.87)	0.1370 *** (117.80)	0.1523 *** (294.44)	0.1536 *** (312.56)
edudum_u	0.3199 *** (320.45)	0.2965 *** (308.74)	0.3055 *** (735.99)	0.2823 *** (711.83)
potexp	0.0258 *** (206.65)	0.0269 *** (225.34)	0.0263 *** (523.61)	0.0291 *** (607.88)
potexpsq	-0.0006 *** (-231.19)	-0.0006 *** (-235.43)	-0.0006 *** (-582.96)	-0.0006 *** (-617.70)
tenure	0.0329 *** (257.41)	0.0310 *** (253.61)	0.0353 *** (648.65)	0.0305 *** (585.13)
tenuresq	-0.0003 *** (-74.26)	-0.0003 *** (-84.89)	-0.0002 *** (-167.04)	-0.0002 *** (-158.30)
lnpopdens	0.0556 *** (211.75)	0.0447 *** (176.13)	0.0587 *** (554.73)	0.0473 *** (465.29)
_cons	2.0357 *** (925.17)	2.3099 *** (965.28)	1.9849 *** (2104.20)	2.2570 *** (2272.32)
Industry dummies	yes	yes	yes	yes
Firm size dummies	no	yes	no	yes
Year dummies	no	no	yes	yes
Number of obs	882,249	882,249	5,131,475	5,131,475
Adj R <sup>2</sup>	0.5602	0.5986	0.6175	0.6552

(Notes) OLS estimates with t-values in parentheses. \* significant at 10%; \*\* significant at 5%;

\*\*\* significant at 1%. Pooled regression is for five years from 1900 to 2009.

Table 4 Estimation Results Using Real Wages

	(1)		(2)		(3)		(4)	
	2009		2009		pooled		pooled	
female	-0.2521	***	-0.2573	***	-0.2449	***	-0.2489	***
	(-257.07)		(-273.70)		(-442.34)		(-468.52)	
edudum_c	0.1318	***	0.1339	***	0.1460	***	0.1471	***
	(99.87)		(105.79)		(198.45)		(208.32)	
edudum_u	0.3182	***	0.2949	***	0.3162	***	0.2946	***
	(295.11)		(283.46)		(533.73)		(514.64)	
potexp	0.0268	***	0.0278	***	0.0290	***	0.0304	***
	(195.32)		(211.67)		(368.45)		(402.34)	
potexpsq	-0.0006	***	-0.0006	***	-0.0006	***	-0.0006	***
	(-215.54)		(-219.32)		(-396.43)		(-405.64)	
tenure	0.0330	***	0.0312	***	0.0329	***	0.0298	***
	(235.05)		(231.61)		(405.86)		(381.68)	
tenuresq	-0.0003	***	-0.0003	***	-0.0002	***	-0.0002	***
	(-69.11)		(-78.40)		(-101.99)		(-105.49)	
lnpopdens	0.0373	***	0.0264	***	0.0340	***	0.0237	***
	(124.74)		(91.08)		(196.31)		(141.57)	
_cons	2.1519	***	2.4197	***	2.1376	***	2.3957	***
	(850.09)		(887.59)		(1440.91)		(1525.30)	
Industry dummies	yes		yes		yes		yes	
Firm size dummies	no		yes		no		yes	
Year dummies	no		no		yes		yes	
Number of obs	735,179		735,179		2,284,664		2,284,664	
Adj R <sup>2</sup>	0.5524		0.5894		0.5762		0.6103	

(Notes) OLS estimates with t-values in parentheses. \* significant at 10%; \*\* significant at 5%;

\*\*\* significant at 1%. Pooled regression is for three years from 2000 to 2009.

Table 5 Estimates for Standard Workers (1990–2009 pooled)

	(1)	(2)	(3)
	All standard workers	SMEs	Single establishments
female	-0.1406 *** (-237.44)	-0.1335 *** (-138.27)	-0.1244 *** (-81.73)
edudum_c	0.0925 *** (117.26)	0.0987 *** (80.62)	0.0993 *** (51.38)
edudum_u	0.2472 *** (438.58)	0.2424 *** (245.60)	0.2547 *** (151.49)
potexp	0.0672 *** (926.64)	0.0595 *** (492.39)	0.0609 *** (316.85)
potexpsq	-0.0009 *** (-481.01)	-0.0009 *** (-259.17)	-0.0009 *** (-179.30)
lnpopdens	0.0460 *** (273.84)	0.0450 *** (155.30)	0.0476 *** (99.96)
_cons	2.0652 *** (1461.75)	1.9983 *** (858.76)	1.9839 *** (518.21)
Industry dummies	yes	yes	yes
Year dummies	yes	yes	yes
Number of obs	1,482,772	466,368	196,533
Adj R <sup>2</sup>	0.7314	0.7069	0.6679

(Notes) OLS estimates with t-values in parentheses. \* significant at 10%;

\*\* significant at 5%; \*\*\* significant at 1%.

Table 6 Estimation Results with the Interaction Term of Education and Density

	(1)	(2)	(3)	(4)
	2009	2009	pooled	pooled
female	-0.2622 *** (-292.50)	-0.2661 *** (-310.57)	-0.2743 *** (-751.86)	-0.2782 *** (-802.66)
edudum_c	0.1361 *** (25.40)	0.1313 *** (25.65)	0.1907 *** (77.37)	0.1987 *** (84.88)
edudum_u	0.2191 *** (50.74)	0.2084 *** (50.49)	0.2820 *** (140.09)	0.2846 *** (148.82)
potexp	0.0258 *** (206.91)	0.0269 *** (225.58)	0.0263 *** (523.34)	0.0291 *** (607.66)
potexpsq	-0.0006 *** (-231.42)	-0.0006 *** (-235.64)	-0.0006 *** (-582.71)	-0.0006 *** (-617.45)
tenure	0.0328 *** (257.13)	0.0309 *** (253.34)	0.0353 *** (648.65)	0.0305 *** (585.20)
tenuresq	-0.0003 *** (-73.90)	-0.0003 *** (-84.53)	-0.0002 *** (-167.05)	-0.0002 *** (-158.47)
lnpopdens	0.0514 *** (147.07)	0.0409 *** (121.72)	0.0587 *** (457.17)	0.0481 *** (392.08)
edudum_c*lnpopdens	0.0002 (0.23)	0.0011 (1.56)	-0.0052 *** (-15.77)	-0.0061 *** (-19.67)
edudum_u*lnpopdens	0.0141 *** (23.85)	0.0123 *** (21.85)	0.0030 *** (11.61)	-0.0004 (-1.54)
_cons	2.0629 *** (772.71)	2.3343 *** (836.93)	1.9852 *** (1849.35)	2.2514 *** (2041.04)
Industry dummies	yes	yes	yes	yes
Firm size dummies	no	yes	no	yes
Year dummies	no	no	yes	yes
Number of obs	882,249	882,249	5,131,475	5,131,475
Adj R <sup>2</sup>	0.5605	0.5988	0.6176	0.6552

(Notes) OLS estimates with t-values in parentheses. \* significant at 10%; \*\* significant at 5%;

\*\*\* significant at 1%. Pooled regression is for five years from 1900 to 2009.

Table 7 Estimation Results with the Interaction Term of Tenure and Density

	(1)	(2)	(3)	(4)
	2009	2009	pooled	pooled
female	-0.2607 *** (-291.11)	-0.2648 *** (-309.31)	-0.2736 *** (-750.81)	-0.2777 *** (-802.36)
edudum_c	0.1347 *** (110.78)	0.1368 *** (117.68)	0.1527 *** (295.39)	0.1540 *** (313.40)
edudum_u	0.3197 *** (320.41)	0.2964 *** (308.69)	0.3052 *** (735.77)	0.2821 *** (711.65)
potexp	0.0256 *** (204.89)	0.0267 *** (223.72)	0.0260 *** (516.20)	0.0288 *** (600.63)
potexpsq	-0.0006 *** (-229.38)	-0.0006 *** (-233.81)	-0.0006 *** (-575.65)	-0.0006 *** (-610.77)
tenure	0.0175 *** (34.10)	0.0180 *** (36.88)	0.0197 *** (86.49)	0.0175 *** (81.06)
tenuresq	0.0001 *** (7.34)	0.0000 ** (2.01)	0.0001 *** (17.34)	0.0001 *** (11.37)
lnpopdens	0.0427 *** (90.93)	0.0340 *** (75.57)	0.0454 *** (227.36)	0.0360 *** (189.70)
tenure*lnpopdens	0.0022 *** (31.09)	0.0019 *** (27.33)	0.0022 *** (71.29)	0.0018 *** (62.36)
tenuresq*lnpopdens	-0.0001 *** (-25.78)	0.0000 *** (-22.88)	-0.0001 *** (-56.98)	0.0000 *** (-48.80)
_cons	2.1259 *** (605.28)	2.3842 *** (676.10)	2.0822 *** (1339.66)	2.3388 *** (1528.81)
Industry dummies	yes	yes	yes	yes
Firm size dummies	no	yes	no	yes
Year dummies	no	no	yes	yes
Number of obs	882,249	882,249	5,131,475	5,131,475
Adj R <sup>2</sup>	0.5608	0.5990	0.6180	0.6555

(Notes) OLS estimates with t-values in parentheses. \* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%. Pooled regression is for five years from 1900 to 2009.



Table 8 Estimation Results with the Interaction Term of Experience and Density

	(1)	(2)	(3)	(4)
	2009	2009	pooled	pooled
female	-0.2591 *** (-289.17)	-0.2631 *** (-307.26)	-0.2713 *** (-744.44)	-0.2752 *** (-795.32)
edudum_c	0.1344 *** (110.63)	0.1366 *** (117.60)	0.1537 *** (297.70)	0.1552 *** (316.47)
edudum_u	0.3213 *** (321.81)	0.2981 *** (310.25)	0.3077 *** (741.03)	0.2848 *** (718.10)
potexp	0.0050 *** (10.14)	0.0063 *** (13.45)	0.0034 *** (16.76)	0.0056 *** (29.16)
potexpsq	-0.0002 *** (-22.37)	-0.0002 *** (-22.39)	-0.0002 *** (-53.33)	-0.0002 *** (-56.87)
tenure	0.0328 *** (257.32)	0.0310 *** (253.58)	0.0352 *** (647.27)	0.0304 *** (584.25)
tenuresq	-0.0003 *** (-74.23)	-0.0003 *** (-84.89)	-0.0003 *** (-167.75)	-0.0002 *** (-159.67)
lnpopdens	0.0226 *** (31.34)	0.0120 *** (17.33)	0.0227 *** (81.23)	0.0097 *** (36.31)
potexp*lnpopdens	0.0030 *** (43.50)	0.0030 *** (45.01)	0.0032 *** (115.09)	0.0033 *** (124.25)
potexpsq*lnpopdens	-0.0001 *** (-35.31)	0.0000 *** (-36.36)	-0.0001 *** (-86.92)	-0.0001 *** (-91.63)
_cons	2.2655 *** (436.84)	2.5385 *** (498.71)	2.2449 *** (1070.02)	2.5300 *** (1239.75)
Industry dummies	yes	yes	yes	yes
Firm size dummies	no	yes	no	yes
Year dummies	no	no	yes	yes
Number of obs	882,249	882,249	5,131,475	5,131,475
Adj R <sup>2</sup>	0.5614	0.5998	0.6190	0.6569

(Notes) OLS estimates with t-statistics in parentheses. \* significant at 10%; \*\* significant at 5%;

\*\*\* significant at 1%. Pooled regression is for five years from 1900 to 2009.

Table 9 Estimates for Standard and Non-standard Workers (1990–2009 pooled)

	(1)	(2)	(3)
	fulltime	standard	non-standard
female	-0.3456 *** (-811.71)	-0.1394 *** (-235.58)	-0.3826 *** (-748.16)
edudum_c	0.1915 *** (314.42)	0.0933 *** (118.38)	0.2225 *** (299.04)
edudum_u	0.3427 *** (701.32)	0.2476 *** (439.52)	0.3575 *** (552.26)
potexp	0.0231 *** (97.02)	0.0498 *** (135.97)	0.0219 *** (69.59)
potexpsq	-0.0004 *** (-88.57)	-0.0006 *** (-59.92)	-0.0004 *** (-62.58)
lnpopdens	0.0177 *** (53.45)	0.0279 *** (81.04)	0.0173 *** (35.56)
potexp*lnpopdens	0.0044 *** (135.93)	0.0024 *** (48.22)	0.0042 *** (95.93)
potexpsq*lnpopdens	-0.0001 *** (-103.64)	0.0000 *** (-34.49)	-0.0001 *** (-80.15)
_cons	2.2583 *** (911.96)	2.1990 *** (834.69)	2.2013 *** (613.15)
Industry dummies	yes	yes	yes
Year dummies	yes	yes	yes
Number of obs	5,131,475	1,482,772	3,648,703
Adj R <sup>2</sup>	0.4686	0.7321	0.4223

(Notes) OLS estimates with t-statistics in parentheses. \* significant at 10%;

\*\* significant at 5%; \*\*\* significant at 1%.

Table 10 Estimation Results with the Interaction Term of Experience and Density (Small- and Medium-Sized Firms, 1990–2009 pooled)

	(1)	(2)	(3)
	fulltime	standard	non-standard
lnpopdens	0.0173 *** (40.28)	0.0259 *** (48.81)	0.0180 *** (31.80)
potexp*lnpopdens	0.0036 *** (89.96)	0.0026 *** (31.85)	0.0034 *** (69.96)
potexpsq*lnpopdens	-0.00006 *** (-73.53)	-0.00004 *** (-19.78)	-0.00006 *** (-61.14)
Number of obs	2,663,353	466,368	2,196,985
Adj R <sup>2</sup>	0.4413	0.7082	0.4153

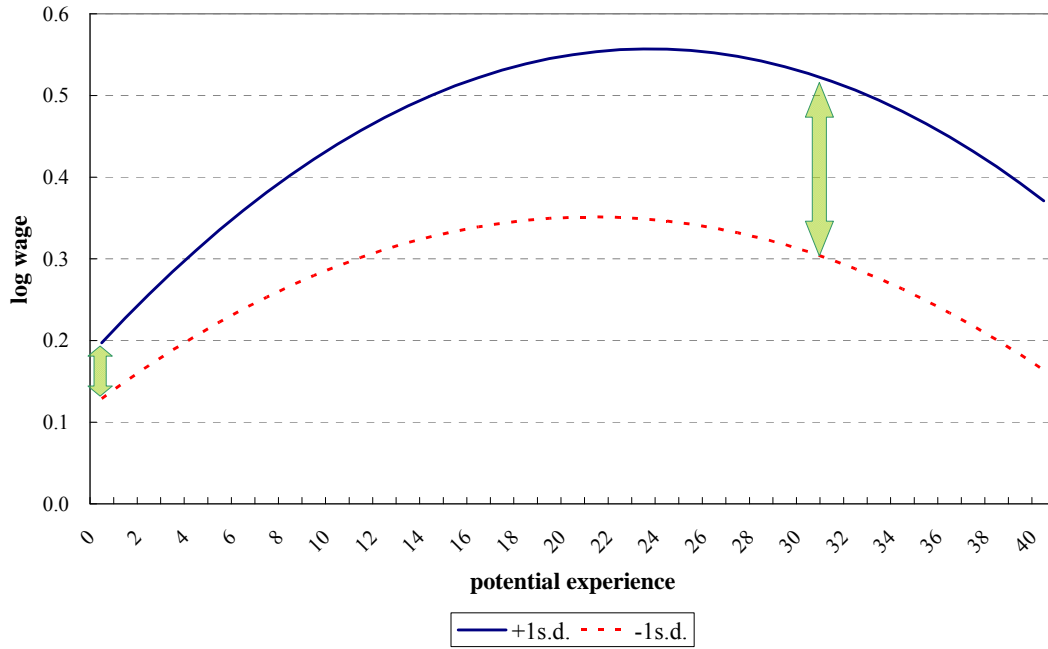
(Notes) OLS estimates with t-statistics in parentheses. \* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%. All regressions include industry dummies, year dummies, sex, education, and potential experience and its square as explanatory variables.

Table 11 Estimation Results with the Interaction Term of Experience and Density (Single Establishments, 1990–2009 pooled)

	(1) fulltime	(2) standard	(3) non-standard
lnpopdens	0.0162 *** (25.90)	0.0260 *** (31.03)	0.0192 *** (24.03)
potexp*lnpopdens	0.0036 *** (63.88)	0.0028 *** (21.34)	0.0033 *** (48.01)
potexpsq*lnpopdens	-0.0001 *** (-52.92)	-0.00004 *** (-10.84)	-0.0001 *** (-41.97)
Number of obs	1,376,441	196,533	1,179,908
Adj R <sup>2</sup>	0.4041	0.6700	0.3875

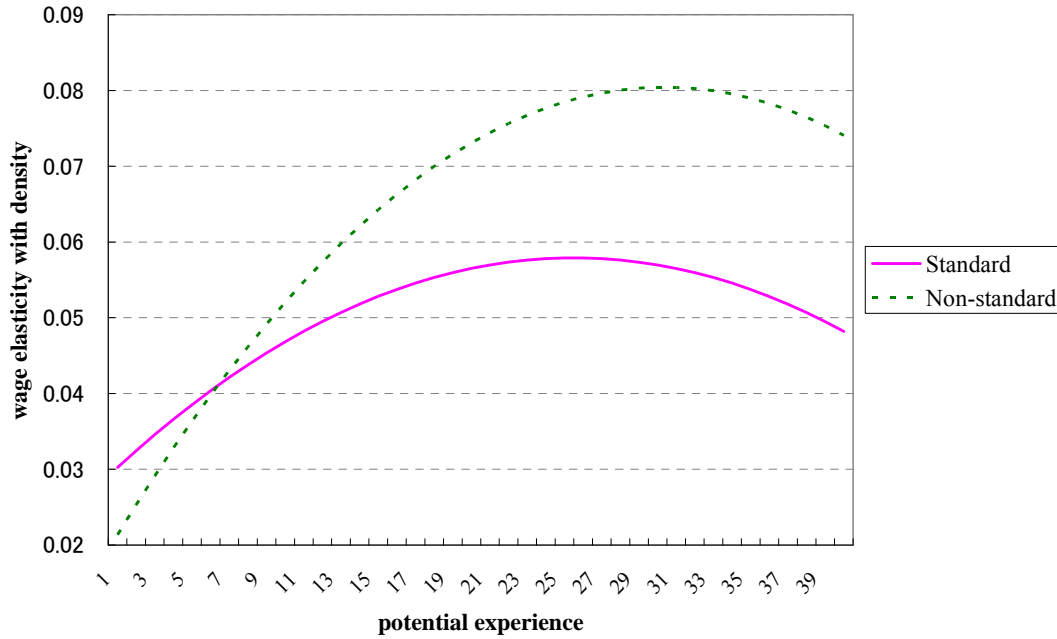
(Notes) OLS estimates with t-statistics in parentheses. \* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%. All regressions include industry dummies, year dummies, sex, education, and potential experience and its square as explanatory variables.

Figure 1 Population Density and Experience-Wage Curve (1990–2009 pooled)



(Notes) The figure is based on the pooled regression result. The lines indicate log population density of cities with  $\pm$  one standard deviation from the mean.

Figure 2 Experience and Wage Elasticity to Density (Standard and Non-standard Workers)



(Notes) The figure is based on the pooled regression results for standard and non-standard workers.