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Inter-city wage differentials and intra-city workplace centralization ☆

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ABSTRACT

We explore the interaction of inter-city and intra-city wage differentials by occupation. The paper makes two main contributions. 1) We construct an occupation-specific index of workplace centralization that accounts for the difference between average employment density from the perspective of employees in each occupation and average employment density from the perspective of all employees. 2) We provide empirical evidence that relative wages of central to non-central occupations increase with city size, or equivalently, the elasticity of wages with respect to city size increases with occupational centrality. We conjecture that this empirical regularity arises because, as city size increases, workers in more central occupations face an increasingly less desirable locus of housing prices and commuting times relative to workers who have jobs in residential areas. The results are robust to the inclusion of individual-specific human capital variables and city-specific fixed effects.

1. Introduction

The study of spatial wage and rent differentials has developed largely along two paths. On one hand, studies of intra-city rent and wage gradients have followed the Alonso–Muth–Mills model. In the basic model, residents choose their proximity to the central business district (CBD), where all production takes place, trading higher rents against shorter commuting times (Alonso, 1964; Muth, 1969; Mills, 1972; Brueckner, 1987; Straszheim, 1987; and White, 1999 provide excellent reviews). Extensions incorporated local employment, endogenous center formation with agglomeration economies, and polycentric employment cities in which several employment centers arise simultaneously (see, for example, Solow, 1973; White, 1988, 1999; Fujita and Ogawa, 1982; Anas and Kim, 1996). Anas et al. (1998) provide a general discussion of modern urban structure.

In these models, within a city, rent and density increase with proximity to the city center(s), while across cities, holding employment accessibility constant, rent increases with city size. Wages are, in turn, higher at employment locations with higher rents, to compensate workers for a less desirable locus of housing prices and commuting times. Eberts (1981), Ihlanfeldt (1992) and McMillen and Singell (1992) found surprisingly strong empirical support for the hypothesis that wages for otherwise similar jobs rise as employment location becomes more centralized.

Glaeser and Kahn (2001) argued that employment decentralization has eroded the wage gradient. However, the process of decentralization has been far from homogeneous across industries (for instance, while manufacturing tends to sprawl within cities, services and idea-intensive industries are likely to be centralized). Empirical studies have not yet systematically examined centralization patterns by occupation, which is a reasonable alternative to analyzing centralization by industry, since a firm may locate different processes in different locations within a city, or even in different cities. For example, lawyers or administrative and financial services workers may have offices located in dense central areas, while production workers may be located in very low-density outlying areas.

On the other hand, studies of inter-city wage and rent differentials have followed the framework developed by Rosen (1979) and Roback (1982, 1988). In this framework, workers and firms weigh differences in intrinsic city characteristics, defined broadly as consumptive or productive amenities, against differences in wages and rents, when choosing a city in which to locate. Workers require higher salaries when faced with higher housing prices or rent, at a given consumptive amenity level. Similarly, at a given productivity level, firms would offer lower wages when faced with higher rents. Wages, rents, and city size adjust, to maintain compensating differentials for differences in intrinsic characteristics in equilibrium. The model has been applied to many topics, including the impact of local government on labor markets (Gyourko and Tracy, 1989, 1991), human capital spillovers

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(Moretti, 2004) and measurement of quality of life and quality of the business environment (Gabriel and Rosenthal, 2004), to name only a few.

Typically, studies of inter-city compensating differentials ignore intra-city centralization and the resulting intra-city rent and wage gradients. Additional insight into inter-city wage differentials by occupation can be attained by blending these two theories. Ours is the first paper in the literature that attempts to do so. The central argument is as follows. Consider two cities, one of which is larger than the other, and two occupations, one of which is "more central" than the other (defined as being located where employment density is, on average, higher). Since workers in the more central occupation face a larger increase in commuting distance (or housing rent) when they move from the smaller city to the larger one, the central to non-central relative wage should be higher in the larger city. Put differently, the elasticity of wages with respect to city size, which we shall subsequently term the *wage premium*, should increase with occupational centralization.

We have two main objectives. The first is to develop an occupation-specific measure of workplace centralization, which we subsequently refer to as the *centrality index*, which can be practically applied to the estimation of inter-city wage differentials across a wide range of cities. The second is to test the hypothesis that relative wages of central to non-central occupations increase with city size, or equivalently, that wage premia increase with the centrality index.

Data on wages, individual characteristics, job characteristics, and within-city workplace location are available for only a small number of cities. Our empirical strategy is to construct indices of occupational centralization for 475 occupational classifications for seven U.S. Metropolitan Statistical Areas (we use the terms MSA and city interchangeably), where such data are available with sufficient geographic detail in the U.S. 2000 Census. We find that occupational centralization is quite consistent across these cities, so, for each occupation, we adopt the simple average of the occupation's index values for all seven cities, as the occupation's single centrality index value. We use this index to proxy within-city workplace location in a regression of individual-level wages across 272 U.S. MSAs. Interacting the centrality index with the log of total MSA employment, we find very strong evidence that wage premia increase with occupational centrality.

Three related phenomena may interfere with identification of the impact of centrality on wage premia. First is the possibility that workers in more central occupations are more educated, and the return to education is higher in larger cities. Second is the possibility that more skilled members of central occupations are more likely to sort into larger cites, in response to higher returns to skill. Third is the possibility that more educated workers tend to be found in more central occupations and to have stronger preferences for the increased urban amenities available in larger cities and more central locations (Glaeser et al., 2001). We argue that our inclusion of detailed individual characteristics, MSA and occupation dummy variables, and, especially, an interaction between education and the log of total MSA employment, controls for these confounding influences, as far as possible.[1]

This paper is organized as follows. Section 2 presents some stylized facts related to our main hypothesis. Section 3 details the construction of the centrality index and describes other data used in our analysis. Section 4 presents the econometric analysis. Section 5 concludes.

2. Some stylized facts

As an example, consider lawyers, who rank at the top of occupations in terms of centrality (see Table 3 below), and production workers, who rank near the bottom. Fig. 1 plots the ratio of the average wage of lawyers to the average wage of production workers, which we shall subsequently term the relative wage, against the logarithm of total MSA employment (see Section 3 for details on how these variables were constructed). The figure shows relative wages increase with city size. We attribute this to the fact that lawyers are more likely to work in more central locations and therefore require larger wage premia than production workers.

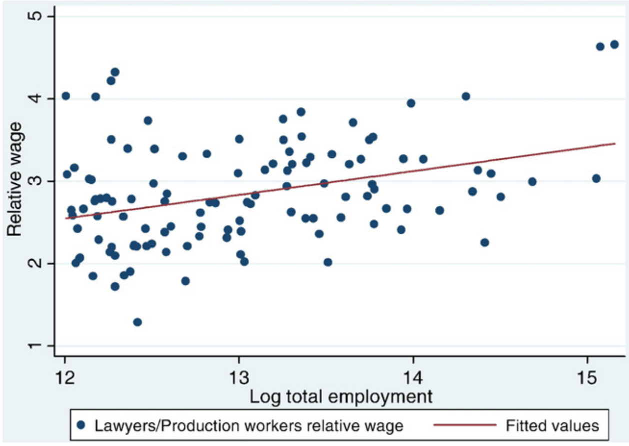


Fig. 1. Lawyers/production workers relative wage and log of total employment. Note: Authors' calculations were made using 5% Sample of the US 2000 Census from the Integrated Public Use Microdata Series.

In order to understand the usefulness of this result, consider a generic firm moving to a new and much larger city. The firm has only two types of workers, lawyers and production workers, and in both cities, lawyers would work in its downtown office and production workers in its outskirts assembly plant. Assume all amenities valued by workers are identical in the two cities. If the firm's goal is to keep workers indifferent between the two cities, the firm's wage structure must adjust upward to compensate for the higher cost of living or the higher commuting time in the larger city. But, should the relative wage change? The pattern in Fig. 1 suggests that lawyers will require a larger relative increase in wages, or, a larger premium, since they are the more central occupation.

Is this representative of a more general pattern? In order to answer this question, for each occupation category, we run a separate regression of the log of the average wage in each MSA on the log of total employment.[2] This yields 475 regression coefficients (one for each occupation) representing the occupation-specific elasticity of wages with respect to total employment, or, the *occupation-specific wage premium*. Fig. 2 plots the wage premia against the centrality index (constructed in Section 3). The positive relationship confirms our hypothesis that more central occupations receive higher premia (t-stat = 5.84, $R^2 = 0.07$). The empirical analysis presented in Section 5 shows that this result is robust to the inclusion of an extensive set of control variables.

3. Occupation centrality and data description

We first construct an occupation-specific index of intra-city workplace centralization, which we refer to as the *centrality index*, using data from the 5% Sample of the U.S. 2000 Census from the Integrated Public Use Microdata Series (IPUMS). IPUMS provides detailed information about household location at the Public Use Micro Area (PUMA) level. PUMAs consist of counties or portions of counties with populations of at least 100,000. The corresponding information about workplace location is available only at a coarser level, Place of

[1] We are indebted to Richard Arnott for pointing out the potential effect of higher preferences for urban amenities among the educated, and for suggesting the interaction between education and city size as a control for these sorting issues.

[2] Similar results are obtained when total employment is replaced by average commuting time, as a *proxy* for city size.

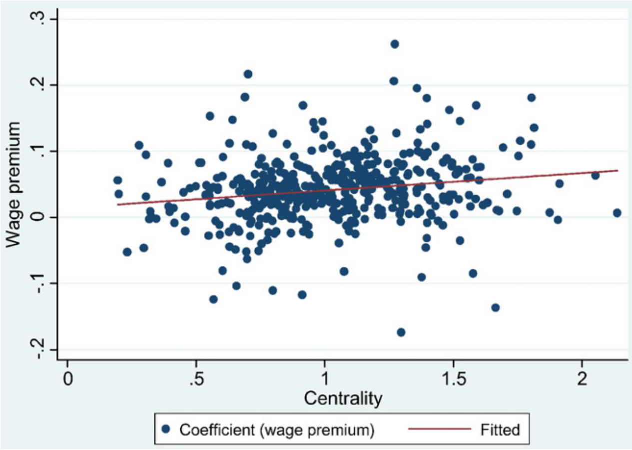


Fig. 2. Wage premia and centrality. Note: Authors' calculations were made using 5% Sample of the US 2000 Census from the Integrated Public Use Microdata Series. The wage premium is defined as the elasticity of wage with respect to city size (using log of total employment).

Work Public Use Micro Areas (PWPUMA). One PWPUMA may contain several PUMAs. Following Timothy and Wheaton (2001), the centrality index is constructed using those cities that contain several PWPUMA (at least ten) and smaller, compact, center-city jurisdictions. Those with a very strong concentration of employment in a single PWPUMA are excluded, for example Los Angeles and New York, where more than 50% of employment is located in a single PWPUMA. The cities selected were Atlanta, Boston, Detroit, Philadelphia, Pittsburgh, Minneapolis and Washington. The selection covers old historical cities like Boston, modern cities like Minneapolis, administrative MSAs like Washington, and an MSA with an especially poor CBD like Detroit.[3]

Let p index the PWPUMAs in MSA c. Let E_p denote employment and A_p denote the area of a given PWPUMA. The employment density in PWPUMA p is $\lambda_p = \frac{E_p}{A_p}$, the number of workers per unit area in PWPUMA p (i.e., workers per square mile). The share of employees in MSA c who work in PWPUMA p is $\omega_p = \frac{E_p}{E_c}$, where E_c denotes total employment in MSA c. For each occupation (indexed by j), let $\omega_{pj} = \frac{E_{pj}}{E_{cj}}$ denote the share of total employment of that occupation in MSA c, with workplace in PWPUMA p. The employment-weighted average employment density of the MSA is $\sum_{p\in c}\lambda_p\omega_p$. If you asked each employee in the MSA what the employment density is at his workplace and then took the average, this would be the result. Thus, this is the average employment density of MSA c from the perspective of the employees. Similarly, the average employment density from the perspective of employees in occupation j in MSA c is $\sum_{p\in c}\lambda_p\omega_{pj}$.

If occupation j is central (i.e., more likely to be located in highly dense areas than the average worker in the city), then the average employment density from the perspective of workers in occupation j will be higher than the average employment density from the perspective of all workers, that is, $\sum_{p\in c}\lambda_p\omega_{pj} > \sum_{p\in c}\lambda_p\omega_p$. The reverse holds for non-central occupations. An occupational centrality index for each city may be defined as:

$$K_{cj} = \frac{\sum_{p\in c}\lambda_p\omega_{pj}}{\sum_{p\in c}\lambda_p\omega_p}. \quad (1)$$

The index has domain on the non-negative real numbers.[4] It represents the average employment density from the perspective of employees in occupation j in MSA c, relative to the average employment density from the perspective of all workers in MSA c. For each city, the employment-weighted average K is 1. An occupation that follows the overall employment pattern will have an index value of 1, occupations with a higher density employment pattern than average (i.e., central) will have index values above 1, and occupations with a lower density employment pattern than average (non-central) will have index values below 1. For each occupation, we define K_j as the simple average of K_{cj} across all the cities considered above in which occupation j is observed.

Figs. 3 and 4 depict λ_p and ω_p for Boston and Minneapolis, respectively, to illustrate how the index is constructed and the intuition behind it. For both cities, the more deeply shaded areas in the figures (representing higher density) generally correspond to the traditional CBD in terms of λ_p, although a different pattern emerges in terms of ω_p. Moreover, changes in λ_p and ω_p are not isotropic with respect to the CBD, that is, they are not uniform in all directions. Similar patterns can be observed for Atlanta, Detroit, Philadelphia, Pittsburgh, and Washington.

The indexes are constructed for each occupation, as categorized by the Standard Occupation Classification (SOC) (475 categories), and for each of the seven MSAs, except for those occupations and MSAs with no workers (i.e., $E_{cj} = 0$). Table 1 presents pair-wise correlation coefficients of the indices for the cities used in this study. For all cases, we observe a positive and significant correlation, with a minimum value corresponding to Detroit–Philadelphia (0.26) and a maximum corresponding to Boston–Minneapolis (0.55). The simple average has a minimum correlation with Detroit (0.48) and a maximum with Pittsburgh (0.80). Finally, we calculate the Kendall coefficient of concordance, to test the degree of association among the rank correlations: using 445 occupations available in all the MSAs, and obtain a highly significant value of 0.55.

These findings suggest strong similarities across MSAs for the set of occupations, which may reveal the existence of a single scalar index which sorts occupations according to their intrinsic *centrality* value. In fact, principal component factor analysis (Table 2) shows that only one factor is behind the centrality indices across MSAs. The factor loadings follow closely the correlation of the simple average index values, K_j, and the MSA-specific index values, K_{jc}.[5] For this reason, we use the average index values, K_j, as our measure of workplace centralization for occupation j.

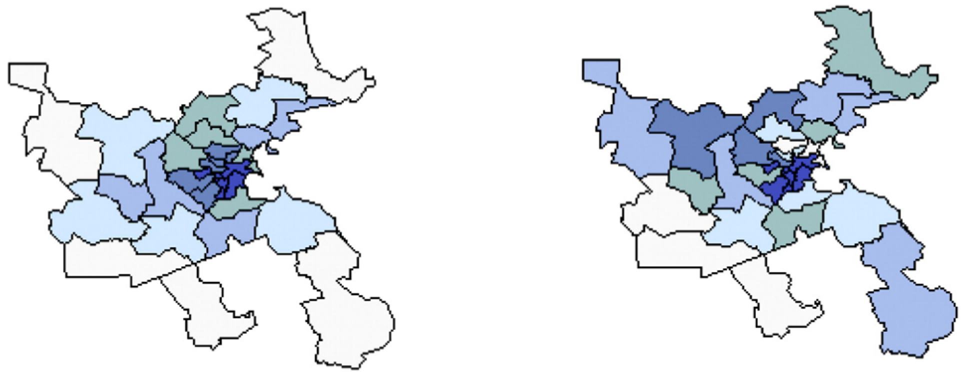
Our occupational centrality measure depends on the relative pattern of employment density, not distance from the CBD, as in other empirical studies (for instance, Eberts, 1981; Ihlanfeldt, 1992; Glaeser and Kahn, 2001). There are three reasons for this construction. First, it is not affected by the definition and selection of the CBD. Second, it allows for the existence of multiple employment centers. Third, distance to the CBD is an isotropic measure (i.e., the same in all directions) and therefore cannot account for the specific geographical features of a city; our index is less affected by city-specific geographic idiosyncrasies.

Table 3 reports the average value and the standard deviation of K_j for broad SOC categories, each of which contains many individual occupations. For each city, the table also presents the rank of the average centrality indices for each occupation group. Lawyers and entertainers are the two broad occupation groups with the highest index values, while agricultural and production workers are the two groups at the opposite extreme. Some of the broad groups contain

[3] Brueckner et al. (1999) claim that "an urban area like Detroit lacks the rich history of Paris, the central-city's infrastructure does not offer appreciable aesthetic benefits. This means that no amenity force is working to reverse the conventional forces that draw the rich to the suburbs. As a result central Detroit is poor." (p. 94).

[4] Undefined for $E_{cj} = 0$.

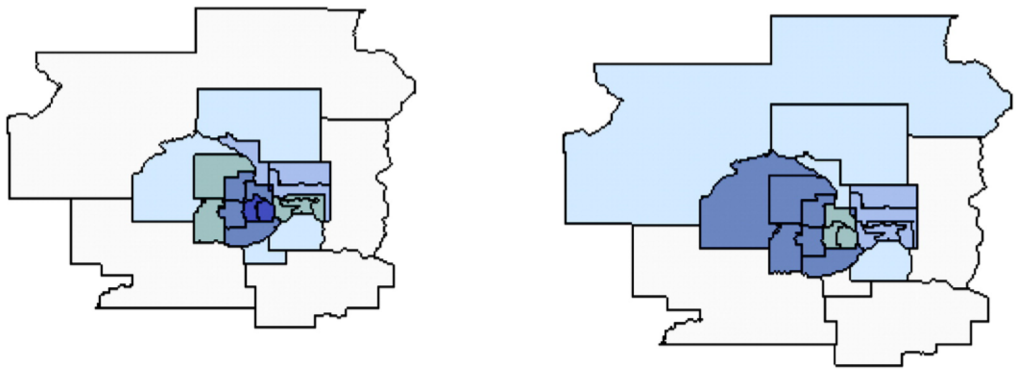
[5] Factor analysis analytic techniques are statistical methods to detect underlying structure in relationships among variables (here we have seven, one for each MSA, each with 475 observations corresponding to a SOC occupation). The principal component analysis extracts underlying factors common to the variables. Factors are sorted depending on the proportion of total variance explained by each. The analysis in Table 2 reveals that one factor explains a significant portion of the variance, and we associate this with the intrinsic centrality value of an occupation.



Employment/Area (employment density by PWPUMA)

Employment/Total Employment (employment share by PWPUMA)

Fig. 3. Concentration indexes, Boston. Note: Authors' calculations were made using 5% Sample of the US 2000 Census from the Integrated Public Use Microdata Series.



Employment/Area (employment density by PWPUMA)

Employment/Total Employment (employment share by PWPUMA)

Fig. 4. Concentration indexes, Minneapolis. Note: Authors' calculations were made using 5% Sample of the US 2000 Census from the Integrated Public Use Microdata Series.

occupations that differ strongly in their location tendencies. For example, despite belonging to the same, broad, classification category, employment of professors is concentrated at colleges and universities, while elementary and secondary teachers are employed at schools scattered across cities.[6]

Although not reported, we also calculate the statistics of Table 3 for men and women separately. Certain occupations have considerable changes, depending on the sub-sample used to calculate the centrality index. For instance, teachers and nurses became more centralized if only men were considered. This result is explained by the fact that women are more likely to prefer to work in the outskirts of the city, near where they live.

In order to test the main hypothesis of this paper, we consider all individuals in the 5% Sample of the U.S. 2000 Census from the 272 MSAs in the United States. We restrict the sample to individuals in the 25–65 age range who are employed (either salaried or self-employed) and work at least 20 h per week. Each individual is assigned the centrality index (K) of his occupation. In addition, we construct individual annual gross wages (in logs, log w), average weekly hours worked (in logs, log *hours*), gender (*FEM*), education (years of schooling, *EDUC*), age (*AGE*), and dichotomous variables for black workers (*BLACK*) and those of Hispanic origin (*HISP*). City size is measured by the logarithm of aggregate employment (log E; only individuals who satisfy the criteria defined above). Finally, we also compute the average commuting time for each MSA (*COM*). For computational purposes, we take a 30% random sample of the 5% Sample U.S. 2000 Census when dummies by state are used, and a 5% random sample when MSA dummies are used.

4. Econometric analysis

Our hypothesis is that wage premia should increase with the centrality index, after controlling for city, occupation, and individual characteristics. Our baseline model is:

$$\log w_{i,cj} = \alpha\left(K_j \times \log E_c\right) + \beta X_i + \eta_c + \mu_j + \varepsilon_i, \qquad (2)$$

where η and μ denote MSA-specific and SOC-specific fixed effects, respectively, X is a set of human capital and other individual-specific variables, and e denotes an individual specific i.i.d. error component. The parameter of interest is α, which tells us whether the elasticity of wages — with respect to total MSA employment — increases with the centrality index. Moreover, α is orthogonal to individuals sorting across cities according to their unmeasured ability (i.e., some cities attract the best/worst workers in each occupation), as this effect is captured by the MSA-specific controls.

Table 4 reports regression results for model (2) under different specifications. All specifications contain dummies for each SOC occupation category (475 categories). The first three columns have dummies by state, and the last three columns contain dummies by

[6] The centrality index for detailed occupation categories and general information on replicability of our results are available at http://www.bebr.ufl.edu/jimd/rsue/occupation_centrality.

Table 1
Pair-wise correlation coefficients of the centrality indexes.

	Average	Atlanta	Boston	Detroit	Minneapolis	Philadelphia	Pittsburgh	Washington
Average	1.000							
	475							
Atlanta	0.645	1.000						
	473	473						
Boston	0.753	0.500	1.000					
	469	468	469					
Detroit	0.485	0.306	0.284	1.000				
	464	462	459	464				
Minneapolis	0.767	0.479	0.545	0.378	1.000			
	459	459	457	454	459			
Philadelphia	0.668	0.361	0.518	0.259	0.449	1.000		
	471	470	467	462	458	471		
Pittsburgh	0.800	0.427	0.423	0.336	0.504	0.360	1.000	
	468	467	463	460	455	466	468	
Washington	0.777	0.503	0.531	0.268	0.524	0.482	0.487	1.000
	468	467	464	459	432	466	463	468

Notes: Each cell contains the pair-wise correlation coefficient of the centrality indexes and the number of occupations used.

Table 2
Principal components factor analysis.

Factors	Eigenvalue	Difference	Proportion	Cumulative
1	3.117	3.016	1.126	1.126
2	0.101	0.112	0.036	1.163
3	−0.011	0.050	−0.004	1.159
4	−0.061	0.015	−0.022	1.136
5	−0.076	0.052	−0.028	1.109
6	−0.129	0.044	−0.046	1.062
7	−0.172	–	−0.063	1.000

Variable	Factor 1	Factor 2	Uniqueness
Atlanta	0.683	0.008	0.534
Boston	0.729	−0.137	0.449
Detroit	0.473	0.187	0.741
Minneapolis	0.731	0.034	0.463
Philadelphia	0.634	0.133	0.581
Pittsburgh	0.668	0.158	0.529
Washington	0.715	−0.058	0.485

MSA. In the former case, we also include log E as a freestanding variable.[7]

For all the cases considered in the table, the estimate of α (the coefficient on $K\times\log E$) is positive and statistically significant.[8] The coefficient of interest is 0.0719 if only log E and state and occupation dummies are included as controls (column 1); including individual-specific human capital variables decreases it to 0.0537 (column 2); and it is reduced to 0.0467 (column 3) if the average commuting time is included as an additional covariate. Our results corroborate Timothy and Wheaton's (2001) findings regarding compensation for average commuting time: adding 10 min to the average commuting time increases wages by 10%.

The inclusion of MSA-specific dummy variables controls for any invariant city-specific characteristics that might affect wages, such as amenities or local government fiscal policy, in addition to commuting time, aggregate employment, and invariant state characteristics. In this case, the centrality effect becomes 0.0732 and 0.0551 without and with human capital controls, respectively (see Table 4, columns 4 and 5). Overall, these results confirm our hypothesis that workers in more central occupations receive larger premia for living in larger cities, and that these premia are not compensation for more (*observable*) human capital. The specification in column 5 is our preferred specification.

To see how to interpret the coefficient of interest, we return to the generic firm example developed in Section 2 and calculate how changes in wages of legal and production workers differ when city size (as measured by the log of total employment) doubles. From Table 3 we find that these occupation groups have average centrality indices of 1.48 and 0.756, respectively. Using the coefficient from the model with occupation, MSA and human capital controls, our preferred specification, the difference in the wage premia between legal workers and production workers is $0.0551(1.48–0.756)=0.0399$, which implies that the wage of legal workers would rise by 2.8% more than that of production workers when city size is doubled, since $2^{0.0399}=1.028$.

We now consider in more detail the three potential confounding influences mentioned in the Introduction. First, education may simply be higher in central occupations than in non-central occupations, and, the return to education may be higher in larger cities. For central workers in larger cities, this might create larger premia that may have nothing to do with higher rents.

Second, skill is not perfectly homogeneous within occupations, and, more skilled workers may sort into larger cities. That is, a typical lawyer in New York City may not be the same as a typical lawyer in Kansas City. If such sorting occurs across all occupations, the MSA dummy variables will pick up higher across-the-board wages in larger cities. If such sorting occurs differentially in more central occupations, it may result in higher wage premia for more central occupations, even if centralization itself does not affect wage premia.

Third, more educated workers may have stronger preferences for the increased urban amenities available in larger cities (Glaeser et al., 2001). Such workers may therefore accept relatively lower wages in larger cities. This will counter the effect we intend to measure, if central occupations have more educated workers. Moreover, this is a potential reason for occupations with more educated workers to locate centrally.

It is plausible to assume that these confounding effects can be captured by interacting education (*EDUC*) and MSA size (log E). First, this directly controls for the possibility of increased returns to education in larger cities. Second, if unmeasured ability is positively correlated with education, as seems likely, this interaction captures the possibility that larger cities may become more attractive to the more productive workers in an occupation, as centrality increases. That is, if neither Doctors nor CPAs nor MBAs nor Lawyers are the same in New York City as in Kansas City, it will be captured by $EDUC\times\log E$. These arguments imply that the coefficient of $EDUC\times\log E$ should be positive. On the other hand, the possibility that more educated

[7] This specification assumes that the MSA-specific effect can be decomposed into a state fixed-effect and city-size premium.

[8] Although not reported, similar results are obtained when $K\times$COM is used instead of $K\times\log E$, that is, when commuting time is used as a *proxy* of city size. Moreover, the results are essentially identical if the log of the centrality index is interacted with log employment.

Table 3
Centrality by occupation category.

SOC broad occupation group		Index average	Index rank							
Code	Title		Average	Atl	Bos	Det	Minn	Phil	Pitts	Wash
23	Legal	1.480 (0.163)	1	2	1	4	1	1	2	1
27	Arts, design, entertainment, sports and media	1.332 (0.183)	2	3	3	3	2	3	6	3
15	Computer and mathematical	1.274 (0.165)	3	1	4	1	6	12	3	4
19	Life, physical, and social science	1.235 (0.322)	4	6	2	5	4	11	4	9
55	Military specific	1.233 (0.212)	5	4	10	6	20	23	1	2
13	Business and financial operations	1.198 (0.252)	6	5	7	2	5	13	5	5
33	Protective service	1.180 (0.235)	7	20	8	9	3	2	7	6
25	Education, training and library	1.110 (0.395)	8	14	9	10	7	6	9	8
21	Community and social services	1.102 (0.158)	9	7	5	14	12	4	8	11
43	Office and administrative support	1.072 (0.193)	10	10	12	7	10	9	12	10
29	Practitioners and technical	1.061 (0.234)	11	11	14	8	9	5	10	17
11	Management	1.037 (0.352)	12	8	15	12	11	14	11	7
35	Food preparation and serving	0.972 (0.088)	13	17	13	15	13	8	17	12
39	Personal care and service	0.965 (0.317)	14	16	11	20	19	7	15	13
17	Architecture and engineering	0.955 (0.318)	15	9	16	18	16	18	13	16
53	Transportation and material moving	0.946 (0.288)	16	13	6	19	14	10	22	14
31	Healthcare support	0.922 (0.110)	17	15	18	22	8	16	18	15
41	Sales and related	0.903 (0.179)	18	12	17	11	15	17	14	19
37	Grounds cleaning and maintenance	0.872 (0.204)	19	18	20	21	21	15	16	18
49	Installation, maintenance and repair	0.811 (0.149)	20	19	21	17	17	21	20	21
47	Construction and extraction	0.764 (0.240)	21	21	19	23	22	20	19	20
51	Production	0.756 (0.232)	22	23	22	13	18	19	21	23
45	Farming, fishing, and forestry	0.638 (0.434)	23	22	23	16	23	22	23	22

Notes: Standard deviations in parentheses.

individuals are willing to pay more for urban amenities means that this coefficient would be negative. Of course, both effects may be present, in which case the coefficient would capture the net effect. The coefficient of interest remains that of $K \times \log E$, and in this case, it is robust to the concurrent presence of the discussed effects.

Table 4, column 6 reports the coefficient estimates of model (2) with the inclusion of $EDUC \times \log E$. The coefficient of the latter is positive and statistically significant, suggesting the existence of higher returns to education in larger cities, or ability sorting. The coefficient estimate of $K \times \log E$ is reduced to 0.0457. This implies that about 20% of the centrality effect in Table 4, column 5 was due to increased returns to education in larger cities, or ability sorting in central occupations. Nevertheless, the coefficient estimate of $K \times \log E$ is still statistically and economically significant, so our main finding is robust to including this interaction. In the generic firm example, the difference in wage premia between legal and production workers is $0.0457(1.48–0.756) = 0.0331$, which implies that wages of legal workers rise by 2.3% more than do wages of production workers, when city size doubles.

To further illustrate the usefulness of our findings, consider the problem of creating an index of the relative cost of hiring equally-qualified workers to do identical jobs in different cities. Based on an estimate of Eq. (2), the predicted log wage is:

$$\log \hat{w}_{i,cj} = \hat{\alpha}\left(K_j \times \log E_c\right) + \hat{\beta}X_i + \hat{\eta}_c + \hat{\mu}_j.^{9} \quad (3)$$

These predicted values can be used to create an index of log wages, $\hat{\Delta}_{cj}$, by specifying a base location, $c = 0$, and calculating the difference in log wages between city c and the base location. Assuming that the base location corresponds to the omitted, city dummy variable, so that $\hat{\eta}_0 = 0$, the index of log wages is $\hat{\Delta}_{cj} = \hat{\alpha}K_j\,(\log E_c - \log E_0) + \hat{\eta}_c$. This may be converted into a relative wage index, I_c, by exponentiating: $\hat{I}_{cj} = e^{\hat{\eta}_c}\,(E_c / E_0)^{\hat{\alpha}K_j}$.

If Eq. (2) were estimated without $K \times \log E$, the predicted log wage would be:

$$\log \hat{\hat{w}}_{i,cj} = \hat{\hat{\beta}}X_i + \hat{\hat{\eta}}_c + \hat{\hat{\mu}}_j. \quad (4)$$

In this case, the index of log wages would simply be $\hat{\hat{\Delta}}_c = \hat{\hat{\eta}}_c$, and the relative wage index would be $\hat{\hat{I}}_c = e^{\hat{\hat{\eta}}_c}$. The difference between the log wage indices based on Eqs. (3) and (4) is $\hat{\Delta}_{cj} - \hat{\hat{\Delta}}_c = \hat{\alpha}K_j\,(\log E_c - \log E_0) + \hat{\eta}_c - \hat{\hat{\eta}}_c$.

To interpret this difference, note that having omitted $K \times \log E$ from the estimation of Eq. (4), the MSA-specific effect, $\hat{\hat{\eta}}_c$, roughly equals $\hat{\eta}_c$ plus the average effect of the difference between $K \times \log E$ in city c and city 0. Ignoring differences in the distribution of occupations across cities, this means $\hat{\hat{\eta}}_c \approx \hat{\eta}_c + \hat{\alpha}\bar{K}\,(\log E_c - \log E_0)$, where $\bar{K}$ is the sample average centrality index. The difference between the log wage indices based on Eqs. (3) and (4) is then $\hat{\Delta}_{cj} - \hat{\hat{\Delta}}_c \approx \hat{\alpha}\,(K_j - \bar{K})\,(\log E_c - \log E_0)$.

Thus, omission of $K \times \log E$ will produce a log wage index that is too high (low) for non-central (central) occupations in cities larger than the base city and too low (high) for non-central (central) occupations in cities smaller than the base city. Further, omission of $K \times \log E$ will generally introduce additional bias in the MSA-specific effect.[10] In particular, the MSA-specific fixed effect will tend to have an additional upward (downward) bias if the city's occupation mix is skewed towards central (non-central) occupations. This is because higher (lower) average wages attributable to higher (lower) than average centrality will be picked up by the MSA-specific fixed effect in addition to the average effect of centrality in cities of similar size.

To illustrate the magnitude of the distortion introduced when centrality is not controlled for, consider comparing predicted wages for elementary, and middle school, teachers (OCC 231), across cities. This occupation is non-central, with a centrality index of 0.779 (<1). Using the baseline specification of Table 4, column 5, we compute the difference between both approaches, that is, $\log \hat{w}_{cj} - \log \hat{\hat{w}}_{cj}$, assuming that the teacher is a white, non-Hispanic woman, age 40, with a bachelor's degree. Fig. 5 shows the difference in predicted log wages when centrality is controlled for, by city size. As expected, the figure shows a negative relation between $\log \hat{w}_{cj} - \log \hat{\hat{w}}_{cj}$ and the

[9] Another possibility would be to regress wages on individual characteristics and an MSA-specific effect, only for a particular occupation. However, that: 1) ignores the information present in data on workers in other occupations, 2) may not be feasible if there are few observations in some cities, 3) may not be helpful if the purpose is to estimate how some characteristic effects one occupation relative to others.

[10] Also, generally, both the occupation-specific effect, μ_j, and, the coefficients on the human capital controls will be biased.

Table 4
Econometric results.

Dep.Var. log wage	(1)	(2)	(3)	(4)	(5)	(6)
$K \times \log E$	0.0719***	0.0537***	0.0467***	0.0732***	0.0551***	0.0457***
	(0.0025)	(0.0022)	(0.0023)	(0.0063)	(0.0056)	(0.0059)
log E	−0.0212***	−0.0045**	−0.0279***			
	(0.0025)	(0.0022)	(0.0023)			
FEM		−0.2172***	−0.2167***		−0.2205***	−0.2208***
		(0.0015)	(0.0015)		(0.0037)	(0.0037)
EDUC		0.0485***	0.0482***		0.0477***	0.0101
		(0.0003)	(0.0003)		(0.0008)	(0.0070)
AGE		0.0810***	0.0810***		0.0811***	0.0811***
		(0.0003)	(0.0003)		(0.0007)	(0.0007)
AGE^2/100		−0.0800***	−0.0800***		−0.0803***	−0.0804***
		(0.0003)	(0.0003)		(0.0008)	(0.0008)
BLACK		−0.0887***	−0.0919***		−0.0885***	−0.0885***
		(0.0020)	(0.0020)		(0.0050)	(0.0050)
HISP		−0.0949***	−0.0981***		−0.0924***	−0.0899***
		(0.0022)	(0.0022)		(0.0055)	(0.0054)
log *hours*		0.9683***	0.9671***		0.9545***	0.9540***
		(0.0032)	(0.032)		(0.0079)	(0.0079)
COM			0.1048***			
			(0.0024)			
$EDUC \times \log E$						0.0028***
						(0.0005)
Controls						
State	Yes	Yes	Yes	No	No	No
MSA	No	No	No	Yes	Yes	Yes
SOC	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	1,154,547	1,154,547	1,154,547	192,469	192,469	192,469

Notes: Standard errors in parentheses. **Significant at 5% level, ***Significant at 1% level. Authors' calculations were made using 5% Sample of 2000 Census from IPUMS. Columns 1–3 use a 30% random sample; columns 4–5 use a 5% random sample.

city's log of total employment. In other words, Eq. (3) produces lower (higher) predicted log wages in large (small) cities for elementary and middle school teachers as compared to Eq. (4). Thus, ignoring the affect of occupational centrality leads to the under-predicting of wages for teachers in small cities and the over-predicting of wages for teachers in large cities. Fig. 5 shows that ignoring centrality over-estimates wages by about 2% in the largest cities and underestimates them by about 2% in the smallest cities. For the largest ten MSAs, which contain 27% of total employment in the 272 MSAs considered, the employment-weighted mean decrease in predicted wages is 1.6%, when centrality is controlled for. For the smallest ten MSAs, which contain 0.43% of total employment in the 272 MSAs considered, the employment-weighted mean increase in predicted wages is 2.3%, when centrality is controlled for.

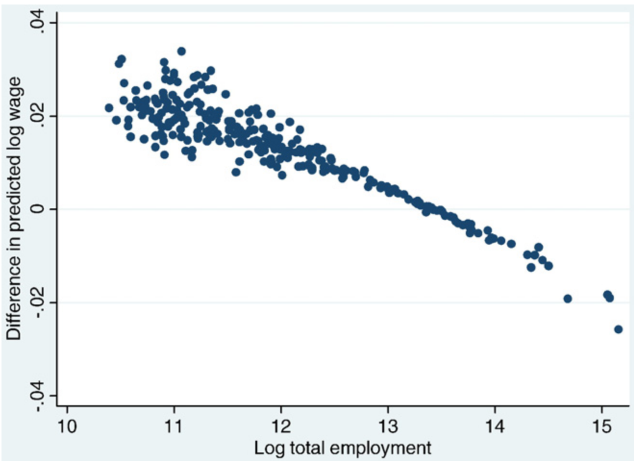


Fig. 5. Predicted difference in teachers log wage. Note: Authors' calculations were made using 5% Sample of the US 2000 Census from the Integrated Public Use Microdata Series.

5. Conclusions and suggestions for future research

The first contribution of this paper is to develop an occupation-specific measure of job centrality that may be practically applied to the estimation of inter-city compensating wage differentials across a wide range of cities. We classify occupations as more or less central, according to the average density of employment where job-holders in those occupations work. We find that occupational centralization is consistent across cities.

The second contribution is to provide strong empirical evidence that wage premia are higher for central occupations than for non-central occupations, where the wage premium is defined as the elasticity of wages with respect to city size. The intuitive idea behind this finding is that workers in central occupations face a less desirable locus of combinations of housing prices and commuting times than those in non-central occupations. This result is robust to the inclusion of individual-specific human capital variables and city-specific fixed effects.

As stated by Crampton (1999), to a great extent, applied urban labor market research has been data-driven. Therefore, the empirical evidence presented in this paper should help guide researchers in the search for an integrated theory of inter-city and intra-city wage differentials.

References

Alonso, W., 1964. Location and Land Use. Harvard University Press, Cambridge (Mass.).

Anas, R., Kim, I., 1996. General equilibrium models of polycentric urban land use with endogenous congestion and job agglomeration. Journal of Urban Economics 40, 232–256.

Anas, A., Arnott, R., Small, K.A., 1998. Urban spatial structure. Journal of Economic Literature 36, 1426–1464.

Brueckner, J.K., 1987. The structure of urban equilibria: a unified treatment of the Muth–Mills model. In: Mills, E.S. (Ed.), Handbook of Regional and Urban Economics, volume II. North-Holland, Amsterdam, pp. 821–845.

Brueckner, J.K., Thisse, J.-F., Zenou, Y., 1999. Why is central Paris rich and downtown Detroit poor? An amenity-based theory. European Economic Review 43, 91–107.

Crampton, G.R., 1999. Urban labour markets. In: Cheshire, P., Mills, E.S. (Eds.), Handbook of Regional and Urban Economics, volume III. North-Holland, Amsterdam, pp. 1499–1557.

Eberts, R.W., 1981. An empirical investigation of intraurban wage gradients. Journal of Urban Economics 10, 50–60.
Fujita, M., Ogawa, H., 1982. Multiple equilibria and structural transition of non-monocentric urban configurations. Regional Science and Urban Economics 12, 161–196.
Gabriel, S., Rosenthal, S., 2004. Quality of the business environment versus quality of life: do firms and households like the same cities? The Review of Economics and Statistics 86, 438–444.
Glaeser, E.L., Kahn, M.E., 2001. Decentralized employment and the transformation of the American city. NBER Working Paper Series #8117.
Glaeser, E., Kolko, J., Saiz, A., 2001. Consumer city. Journal of Economic Geography 1, 27–50.
Gyourko, J., Tracy, J., 1989. The importance of local fiscal conditions in analyzing local labor markets. Journal of Political Economy 97, 1208–1231.
Gyourko, J., Tracy, J., 1991. The structure of local public finance and the quality of life. Journal of Political Economy 99, 774–806.
Ihlanfeldt, K.R., 1992. Intra-urban wage gradients: evidence by race, gender, occupational class, and sector. Journal of Urban Economics 32, 70–91.
McMillen, D.P., Singell, L., 1992. Work location, residence location, and the intraurban wage gradient. Journal of Urban Economics 32, 195–213.
Mills, E.S., 1972. Urban Economics. Scott Foresman, Glenview, Illinois.
Moretti, E., 2004. Human capital externalities in cities. In: Henderson, J.V., Thisse, J.-F. (Eds.), Handbook of Regional and Urban Economics, volume IV. North-Holland, Amsterdam, pp. 2243–2291.
Muth, R., 1969. Cities and Housing. University of Chicago Press, Chicago.
Roback, J., 1982. Wages, rents, and the quality of life. Journal of Political Economy 90, 1257–1278.
Roback, J., 1988. Wages, rents, and amenities: differences among workers and regions. Economic Inquiry 26, 23–41.
Rosen, S., 1979. Wages-based indexes of urban quality of life. In: Mieszkowski, P., Straszheim, M. (Eds.), Current Issues in Urban Economics. Johns Hopkins University Press, Baltimore, pp. 74–104.
Solow, R., 1973. On equilibrium models of urban location. In: Parkin, M. (Ed.), Essays in Modern Economics. Longmans, London, pp. 2–16.
Straszheim, M., 1987. The theory of urban residential location. In: Mills, E.S. (Ed.), Handbook of Regional and Urban Economics, volume II. North-Holland, Amsterdam, pp. 717–757.
Timothy, D., Wheaton, W.C., 2001. Intra-urban wage variation, employment location and commuting times. Journal of Urban Economics 50, 338–366.
White, M., 1988. Location choice and commuting behavior in cities with decentralized employment. Journal of Urban Economics 24, 129–152.
White, M., 1999. Urban areas with decentralized employment: theory and empirical work. In: Cheshire, P., Mills, E.S. (Eds.), Handbook of Regional and Urban Economics, volume III. North-Holland, Amsterdam, pp. 1375–1410.