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Inter-city Compensating Wage Differentials and Intra-city Workplace Centralization

(Old title: An Inter-urban Wage Test of the Monocentric Model)

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Abstract: We explore the interaction of inter-city and intra-city compensating wage differentials by occupation. Our conjecture is that more central occupations receive higher wage premiums in larger cities, since workers in those occupations face a less desirable locus of housing prices and commuting times than those who have jobs in residential areas. The two main contributions of the paper are: 1) construction of an index of occupational centralization that accounts for differences between the density of employment where job holders in an occupation work and the overall employment density pattern, and 2) empirical confirmation that compensating differentials in larger cities are larger for more central occupations. The results are robust to the inclusion of individual-specific human capital variables and city-specific controls. These findings have implications for wage indexes used to construct real wage measures for academic research or in funding formulas where resource allocations are adjusted for labor cost differences across areas.

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1. Introduction

The theory of spatial compensating differentials developed largely along two paths. Studies focused on intra-city rent and wage gradients followed the Alonso-Muth-Mills model (Alonso, 1962, Muth, 1969 and Mills, 1972). Studies focused on inter-city variation in wages and rents followed the Rosen-Roback model (Rosen 1972 and Roback 1982 and 1988). The Rosen-Roback framework continues to have numerous practical applications in research and policy. Gabriel and Rosenthal (2004) is one recent example of numerous studies measuring urban quality of life and the quality of the business environment. Moretti (2004) applies this model to measure human capital spillovers. Glaeser (1998) analyzes proposals to adjust transfer payments for differences in local cost of living. To equalize educational opportunity across school districts, many states adjust funding for differences in the cost of hiring similarly qualified teachers in different cities (National Conference of State Legislatures, 2008). Implicitly or explicitly, these policies are based on the measurement of inter-city compensating wage differentials (Fowler and Monk, 2001).

Typically, studies of inter-city compensating differentials ignore intra-city centralization and the resulting intra-city rent and wage gradients. However, if rents are differentially higher in the denser areas of larger cities, inter-city compensating differentials in larger cities must be larger for more centralized jobs than for less centralized jobs in equilibrium. Thus, we argue that correct inter-city wage comparisons must hold constant the relative location of employment within cities. We have two main objectives; first, to develop a measure of job centrality that may be practically applied to the estimation of inter-city compensating wage differentials across a wide range of cities, and second, to test the hypothesis that more centralized employment locations lead to larger compensating differentials in larger cities.

Data on wages, individual characteristics, job characteristics, and within city workplace location is available for only a small number of cities. Our empirical strategy is to construct an index of occupational centralization for 475 occupational classifications for seven US cities where such data is available with sufficient geographic detail. We find that occupational centralization is quite consistent across these cities. We then use this index to proxy within city workplace location in a regression of individual level wages across 272 US Metropolitan Statistical Areas (we use the terms MSA and city interchangeably). Interacting the occupational centrality index with the log of total MSA employment, we find very strong evidence that occupations that tend to locate more centrally receive larger wage premiums in larger MSAs than do occupations that tend to locate less centrally.

Three related phenomena may interfere with identification of the impact of centralization on inter-city compensating differentials. 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 (who tend be in more central occupations) have stronger preferences for the increased urban amenities in larger cities and more central locations (Glaeser, Kolko and Saiz, 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 as far as possible for these confounding influences.[2]

The remainder of the paper is organized as follows. Section 2 presents some stylized facts related to our main hypothesis. Section 3 considers the theoretical background and underpinnings of our argument. Section 4 details our measure of occupational centrality and describes other data used in our analysis. Section 5 presents the econometric analysis. Section 6 considers the implications of our findings for the construction of wage indices. Section 7 concludes.

2. Some stylized facts and main hypothesis

If an occupation is central, then its workers face a less favorable trade-off between commuting time and high rents, and as a result wage premiums should increase more

[2] 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.

with city size relative to non-central occupations. As an example, consider lawyers who rank at the top of occupations in terms of centrality (see Table 3 below) and production workers, who are in the least central occupation categories. Also consider the relative city-occupation wage premium constructed as $\frac{\overline{w}_{c,L}}{\overline{w}_{c,P}}$, where $\overline{w}_{c,j}$ denotes the average wage in city *c* and occupation *j (=L: lawyers, P: production workers)* (see the following section for details about how these variables were constructed).

Figure 1 reports the relative wage premiums for these two occupations as a function of city size, where this is measured by the logarithm of total employment. The figure shows that the relative premium increases with city size. We attribute this to differences in the occupation centrality, that is, to the fact that lawyers are more likely to work in the Central Business District (CBD), and therefore require a higher relative compensation in large cities than production workers. The empirical analysis below shows that this result can be extended to all occupations, and that it is robust to the inclusion of additional controls.

In order to understand the usefulness of this result, consider the example of a generic firm that is considering moving to a city which exactly doubles the employment size. Moreover, assume that this firm has two types of workers, legal and production workers, and that it seeks for the right compensation scheme to keep its employees exactly indifferent between working in the small and the big city. In both cities, lawyers would be working in its downtown office and production workers in its outskirts assembly plant. The firm needs to adjust wages in order to compensate its workers for the higher cost of living or higher commuting time, but should the firm adjust wages equally for all occupations? The results in Section 5 imply that legal workers, a typical central occupation, should receive a higher premium than production workers. In other words, intra-firm wage differences will increase as a result of moving to a larger city.

Is this the result of a more general pattern? In order to answer this question we run a simple regression model for each occupation category, where the log of the average wage in each MSA is regressed against our measure of city size, log of total employment[3]. In each case we obtain 475 regression coefficients (one for each occupation) that measure how wages in each occupation are related to city size. If our hypothesis is true, more central occupation should have larger coefficients than non-central occupations. Then, we plot them against the centrality index constructed as in the following section. The positive relation depicted in Figure 2 confirms the hypothesis that more central occupations receive higher premiums in larger cities (with logarithm of employment t-stat=5.84, R^2=0.07).

3. Background and Theoretical Underpinnings

The framework developed by Rosen (1979) and Roback (1982, 1988) explains rent and wage variation across cities in terms of intrinsic city characteristics, defined broadly as amenities (consumptive or productive). In these models 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. Assuming the supply of land for household and firm use is not perfectly elastic, rent grows with city size, and wages, rent, and city size adjust to maintain compensating differentials for differences in intrinsic characteristics in equilibrium.

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

Productive amenities, such as infrastructure quality, increase the number of firms wishing to locate in the city at a given rent and wage level. The resulting upward pressure on rent means wages must be higher to compensate workers. Consumptive amenities, such as good weather, increase the number of workers that wish to locate in a city at any given rent and wage level. The resulting upward pressure on rents means wages must be lower to compensate firms. In the presence of agglomeration economies, an increase in city size due to either productive or consumptive amenities makes the city more attractive to firms. This additional upward pressure on rents exacerbates the increase in wages due to city specific productive amenities and mitigates or may overwhelm wage reductions due to consumptive amenities.

The traditional intra-urban wage theory was built around the Alonso-Muth-Mills monocentric model where residents choose their proximity to the CBD where all production takes place, trading higher rents against shorter commuting times (Alonso, 1962, Muth, 1969 and Mills, 1972; Brueckner, 1987, Straszheim, 1987 and White, 1999 provide excellent reviews). Extensions of the basic model incorporated local employment, endogenous center formation with agglomeration economies, and polycentric employment cities in which several employment centers arise simultaneously (for example Solow 1973, White 1988 and 1999, Fujita and Ogawa 1982, and Anas and Kim 1996). Anas, Arnott and Small (1998) provide a general discussion of the modern urban structure.

Centralization in such models may arise from intrinsic advantages at particular locations, such as transportation nodes, or, perhaps more fundamentally, from agglomeration economies owing to increasing returns to scale or to the potential for increased creative interaction. Whatever the reason for centralization, rent increases with distance from the urban fringe and with density for any given city size. Further, density and rent at any particular location increase with city size. Rent at the urban fringe is determined by the opportunity cost of land in non urban uses. 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 Singer (1992) find surprisingly strong empirical support for the hypothesis that wages for otherwise similar jobs rise as employment location becomes more centralized.

We argue that centralization and the resulting intra-city rent and wage gradients have important implications for the measurement of inter-city compensating differentials. All else equal, occupations that tend to locate at more dense or more central locations must receive differentially higher wage premiums in larger cities to compensate for differentially higher rents or longer commutes. Studies of inter-city wage variation that do not control for intra-city job location will overestimate wages for non central jobs and underestimate wages for central jobs in large cities. The reverse is true in small cities.

Glaeser and Kahn (2001) argue that the decentralization of employment has eroded the wage gradient, but the process of decentralization has been far from homogeneous across industries. 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. However, since a firm may locate different processes in different locations within a city, or even in different cities, it is a reasonable alternative to analyzing centralization by industry. For example, lawyers or administrative and financial services workers may have offices located in dense central areas while production workers may be in very low density outlying areas.

4. Occupation centrality and data description

The 5% Sample of the US 2000 Census from the Integrated Public Use Microdata Series (IPUMS) provides detailed information about household location at the level of Public Use Micro Areas (PUMA) which 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 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 which contain several PWPUMA (at least ten) and smaller compact center city jurisdictions, except those with very strong concentration in a single PWPUMA, such as Los Angeles or 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[4]. We use these seven cities to construct a centrality index for every occupation category.

Let i index the PWPUMAs in MSA c. Let E_i denote employment and A_i denote the area of a given PWPUMA. The employment density in the PWPUMA is $\lambda_i = \frac{E_i}{A_i}$, the number of workers per area unit (i.e. workers per square mile). The share of MSA employment with workplace in the PWPUMA is $\omega_i = \frac{E_i}{E_c}$, where E_c denotes total

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[4] Brueckner, Thisse and Zenou (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)

employment in MSA c. For each occupation j, let $\omega_{ij} = \frac{E_{ij}}{E_{cj}}$ denote the share of total employment of that occupation in MSA c with workplace in the PWPUMA i. The average employment density of the MSA is then $\sum_{i \in c} \lambda_i \omega_i$ and the average employment density at the workplaces of occupation j is $\sum_{i \in c} \lambda_i \omega_{ij}$. If occupation j is central (i.e. more likely to be located in highly dense areas than the average worker in the city) then we should have $\sum_{i \in c} \lambda_i \omega_{ij} > \sum_{i \in c} \lambda_i \omega_i$; while the reverse should hold for a non-central occupation. Therefore, a centrality index can be constructed as:

$$(1) \qquad K_{cj} = \frac{\sum_{i \in c} \lambda_i \omega_{ij}}{\sum_{i \in c} \lambda_i \omega_i}$$

The index has domain on the non-negative real numbers[5] and represents the employment density at the workplaces of workers in occupation j in MSA c relative to overall employment density in MSA c. For each city, the employment weighted average K is 1. Thus, an occupation that follows the overall employment pattern should have a value of 1, occupations that are likely to be located in a PWPUMA with high employment density (i.e. central) should have a value above 1, and occupations mostly located in the outskirts of the city (non-central) should have a value below 1.

Our occupation centrality measure (K) is not constructed as in other empirical studies as the distance with respect to the CBD (for instance Eberts, 1981; Ihlanfeldt,

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

1982; Glaeser and Kahn, 2001), but as an average employment density measure. Three reasons can be named for this construction. First, it is not affected by the definition and selection of the CBD. Second, focusing on density at the place of employment allows for the existence of multiple employment centers. Third, distance to the CBD is an isotropic measure (i.e. the same in all directions) which implies that it cannot account for the specific geographical patterns of the city, and our use of PWPUMA structure allows for more geographical flexibility in this sense.

For each occupation we construct a centrality index (*K*) which is defined as the simple average for all the cities considered above. To illustrate how the index is constructed, Figures 3 and 4 depict λ_i and ω_i for Boston and Minneapolis respectively, and they show the intuition behind the index. For both cities, more colored areas (representing higher density) generally correspond to the traditional CBD in terms of λ_i, although a different pattern emerges in terms of ω_i. Moreover, changes in λ_i and ω_i are not isotropic with respect to the CBD, that is, they are not uniform in all directions. Similar patterns can be observed for the rest of the cities used for the construction of K.

The indexes are constructed for each occupation as categorized by the Standard Occupation Classification (SOC) given in the data (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 pairwise correlation coefficients for the cities used in this study. For all cases we observe a positive and significant correlation, with a minimum value corresponding to the comparison Detroit-Philadelphia (0.26) and a maximum corresponding to Boston-Minneapolis (0.55). The constructed 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 concentration indices across MSAs. The factor loadings follow closely the correlation of the average *K* for the MSAs considered here and the MSA specific index. For this reason we use the average *K* as an overall centrality measure by occupation.

Table 3 reports average *K* and ranks for broad SOC categories. Lawyers and entertainers is the broad occupation group with the highest index values, while agricultural and production workers appear at the opposite extreme. Within the major categories we also observe a large dispersion in the education related categories. This is likely because, 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. 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 are 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 US 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), working at least 20 hours per week. Each individual in a given occupation is attached to a given value of centrality measure (*K*). 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 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 city commuting time (*COM*). For computational purposes, we take a 30% random sample of the 5% Sample US 2000 Census when dummies by state are used and a 5% random sample when MSA dummies are used.

5. Econometric analysis

Our hypothesis is that more central occupations should receive higher premiums in larger cities as compensation for greater increases in rent (or commuting cost). That is, central occupations should have a higher wage premium in bigger cities, after controlling for city, occupation, and individual characteristics. In order to study the validity of this hypothesis, we consider a fixed effects baseline model of the form:

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

η and μ denote MSA specific and SOC specific fixed effects respectively, and ε denotes an individual i.i.d. error component. *X* is a set of human capital and other individual specific variables. The parameter of interest is α, which tells us whether central occupations earn higher premiums in bigger cities. Moreover α is orthogonal to potential ability sorting coming from 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 MSA-specific controls. Table 4 reports the 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 two columns contain dummies by MSA. In the former case, we also include log *E* as a freestanding variable[6].

For all the cases considered in the table we observe a positive and significant estimate of α (the coefficient on K× log E).[7] 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 minutes to the average commuting time increases wages by 10%.

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 (sees Table 4, columns 4 and 5). Overall, these

[6] This specification assumes that the MSA-specific fixed effect can be decomposed in a state fixed-effect and city-size premium.
[7] Although not reported, similar results are obtained when K × COM is used instead of K × 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.

results confirm our hypothesis that workers in more central occupations are likely to receive larger premiums for living in larger cities, and that these premiums 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 the changes in the wages of legal and production workers would differ in the case that the firm moves to a city that doubles its employment size. The increase in the logarithm of wages for a given occupation is simply $\alpha K \log(2)$. From Table 3 we get that these occupations have centrality indices of 1.48 and 0.756 respectively. Using the coefficient from the model with MSA and human capital controls, our preferred specification, the increase in the log wages of legal workers should exceed the increase in the log wages of production workers by $0.0551(1.48\text{-}0.756)\log(2)$, or about 3%.

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 non-central occupations, and, the return to education may be higher in larger cities. This might create larger premiums for central workers in larger cities that may have nothing to do with higher rents.

Second, skill is not perfectly homogenous 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 it occurs differentially in more central occupations, it may result in higher premiums for more central occupations in larger cities even if centralization itself does not affect wages

Third, more educated individuals may have stronger preferences for the increased urban amenities offered in larger cities (Glaeser, Kolko and Saiz, 2001). Indeed, if a central location provides more access to such amenities, this a reason to expect occupations with higher education levels to be more centralized. It also means such workers will accept lower wages in compensation for the increased urban amenities available in larger cities and in more central locations, countering the effect we intend to measure since central workers tend to be more educated.

It is plausible to assume that these confounding effects can be captured by the interaction of the education variable (EDUC) and MSA size (log E). On one hand, this directly controls for the possibility of increased returns to education in larger cities and captures ability sorting in two ways. First, unmeasured ability is likely to be positively correlated with education levels. Second, and more importantly, if higher returns to ability attract the most productive workers to larger cities in all occupations with high levels of education, it will be captured by this interaction. 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 × log E. These arguments imply that the coefficient of EDUC × log E should be positive. On the other hand, the possibility that more educated individuals are willing to pay more for urban amenities means this coefficient should be negative. Of course, both effects may be present, in which case the coefficient captures the difference of the two. The coefficient of interest remains to be that of K × log E, and in this case, it would be robust to the concurrent presence of the discussed effects.

Table 4, column 6, reports the coefficient estimates of model (2) with the additional inclusion of EDUC × log E. It can be observed that the coefficient of the latter is positive and statistically significant, which suggests 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 with central occupations But, the coefficient estimate of $K \times \log E$ is still statistically and economically significant, so our main finding is robust to including this interaction.

We note that if labor and land markets equilibrate both within and across cities, and if this additional return is only possible in more central locations, higher returns to skill in central areas are simply an agglomeration economy that will be priced into the rent gradient and which should be regarded as a part of the additional compensating differential for more central locations in larger cities. Arguably then part of what is captured by the effect of the interaction of EDUC × log E should still be considered as part of the centrality premiums we intend to measure.

6. Implications for construction of wage indices

The results presented above have implications for wage indices used in applied research and funding formulas. First, studies that use indices of the cost of living or wages to create real wage measures, for example to explain job turnover, should account for job centralization, or they will not correctly measure the effect of real wages. Second, resource allocation and employee compensation schemes such as those used by many states in efforts to equalize real education spending across school districts should account for the relative centralization of workplace location as an important determinant of wage differentials. In particular, if the objective is the construction of an index of the cost of attracting equally qualified workers in different geographic areas, wage differentials should take into account the *centrality* attribute of each occupation.

We consider this application in more detail since it is of immediate and practical concern in the allocation of sizeable amounts of state and local funding. Indeed, the authors' responsibility calculating just such an index for use in Florida's public education finance system spurred our initial interest in the topic. As a first approximation to this problem, consider estimating equation (2) without including the centrality variable. In that case, the predicted market wage in city *c* for occupation *j* can be estimated by:

$$(3)\ \log \hat{w}_{cj} = \hat{\beta} X_j + \hat{\eta}_c + \hat{\mu}_j$$

The hypothesis in this paper predicts that occupational centrality will affect the estimation of both η_c and μ_j. First, the MSA-specific effect will be upward (downward) biased if the city's occupation mix is skewed towards central (non-central) occupations. Second, the occupation-specific effect will also be upward (downward) biased if it is a central (non-central) occupation.

Consider the problem of constructing a compensation scheme for public school employees, generally non-central occupations, across different cities. Without controlling for centrality, non-central (central) workers living in a large city would receive more (less) compensation than the minimum they are willing to accept for working there and the opposite would hold in small cities. This is because, as a non-central occupation, they do not face the steep rent gradients more central occupations do. In that case, a better estimate would be given by the predicted wage of an average teacher using the full equation (2):

$$\text{(4)}\quad \log \hat{\hat{w}}_{cj} = \hat{\hat{\alpha}}\left(K_j \times \log E_c\right) + \hat{\hat{\beta}} X_j + \hat{\hat{\eta}}_c + \hat{\hat{\mu}}_j$$

Using the baseline specification of Table 4, column 5, we compute the difference between both approaches, that is $\log \hat{\hat{w}}_{cj} - \log \hat{w}_{cj}$, for elementary and middle school teachers (OCC 231; assumed to be a white non-Hispanic woman, age 40, with a bachelor's degree). These differences are plotted in Figure 5. As expected, the figure shows a negative relation between $\log \hat{\hat{w}}_{cj} - \log \hat{w}_{cj}$ and the city's log of total employment. In other words, a compensation scheme based on equation (4) would produce lower (higher) wages in large (small) cities as compared to equation (3). Thus, ignoring the affect of occupational centrality would lead to a compensation scheme in which schools in small cities could not compete as effectively as schools in large cities for teachers of the same quality.

7. Conclusions and suggestions for future research

We find suggestive evidence that indicates that central occupations, defined as those occupations which are more likely to have a workplace location in high employment density areas, receive higher premiums relative to non-central occupations in larger cities. 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. 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 and intra urban wage differentials.

The findings reported in this paper have implications for wage indices used in applied research and funding formulas. Studies that use indices of the cost of living or wages to create real wage measures, for example to explain job turnover, should account for job centralization. Resource allocation and employee compensation schemes such as those used by many states in efforts to equalize real education spending across school districts should also account for the relative centralization of workplace location as an important determinant of wage differentials. Otherwise, resource allocations will be too low in small cities for non-central workers and too low in big cities for central workers..

References

- Arnott, R., 2001, Urban economic aggregates in monocentric and non-monocentric cities, Boston College Working Papers in Economics 506, Boston College Department of Economics.
- Anas, A., R. Arnott and K.A. Small, 1998, Urban spatial structure, Journal of Economic Literature 36, 1426-1464.
- Anas, R., and I. Kim, 1996, General equilibrium models of polycentric urban land use with endogenous congestion and job agglomeration, Journal of Urban Economics 40, 232-256.
- Alonso, W., 1964, Location and land use (Harvard University Press, Cambridge, MA).
- Brueckner, J.K., 1987, The structure of urban equilibria: A unified treatment of the Muth-Mills model, in: E.S. Mills, ed., Handbook of Regional and Urban Economics, Vol. 2 (North-Holland, Amsterdam), 821-45.
- Brueckner, J.K., J-F. Thisse and Y. Zenou, 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: P. Cheshire and E.S. Mills, eds., Handbook of Regional and Urban Economics, Vol. 3 (North-Holland, Amsterdam), 1499-557.
- Fowler, W., and D. Monk, 2001, A primer for making cost adjustments in education, National Center for Education Statistics, U.S. Department of Education, NCES 2001-323.
- Fujita, M., and H. Ogawa, 1982, Multiple equilibria and structural transition of non-monocentric urban configurations, Regional Science and Urban Economics, 12, 161-196.
- Gabriel, S. and 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(1): 438-444.

- Glaeser, E.L., 1998, Are cities dying? Journal of Economic Perspectives 12, 139-160.
- Glaeser, E.L., 1998, Should transfer payments be indexed to local price levels? Regional Science and Urban Economics 28: 1-20.
- Glaeser, E.L. and M.E. Kahn, 2001, Decentralized employment and the transformation of the American city, NBER Working Paper Series #8117.
- Glaeser E., J. Kolko, and A. Saiz, 2001, Consumer City, Journal of Economic Geography, 1, 27-50.
- Ihlanfeldt, K.R., 1992, Intra-urban wage gradients: Evidence by race, gender, occupational class, and sector, Journal of Urban Economics 32, 70-91.
- Mills, E.S., 1972 Urban economics (Scott Foresman, Glenview, Illinois)
- Moretti, E., 2004, Human capital externalities in cities, in: V. Henderson and J.F. Thisse, eds., Handbook of Regional and Urban Economics, Vol. 4 (North-Holland, Amsterdam).
- Muth, R., 1969, Cities and Housing (University of Chicago Press, Chicago)
- National Conference of State Legislatures, 2008, Geographic cost adjustments in education. (March 20th) http://www.ncsl.org/programs/educ/PubsGeo.htm
- Roback, J., 1982, Wages, rents, and the quality of life, Journal of Political Economy 90, 1257-78.
- 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: P. Mieszkowski and M. Straszheim, eds., Current Issues in Urban Economics (Johns Hopkins University Press, Baltimore).
- Solow, R., 1973, On equilibrium models of urban location, in: M. Parkin, ed., Essays in Modern Economics (Longmans: London) 2-16.
- Straszheim, M., 1987, The theory of urban residential location, in: E.S. Mills, ed., Handbook of Regional and Urban Economics, Vol. 2 (North-Holland, Amsterdam), 717-757.
- Timothy, D. and W.C. Wheaton, 2001, Intra-urban wage variation, employment location and commuting times, Journal of Urban Economics 50, 338-366.

- White, M., 1998, 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: P. Cheshire and E.S. Mills, eds., Handbook of Regional and Urban Economics, Vol. 3 (North-Holland, Amsterdam), 1375-1410.

Table 1 – Pairwise correlation coefficients of the centrality indexes

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

Notes: Each cell contains the pairwise 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

Table 3 - Centrality by occupation category

SOC category	Category of Occupation	Rank	K	Atl	Bos	Det	Minn	Phil	Pitts	Wash
23	**Legal**	1	1.480 (0.163)	2	1	4	1	1	2	1
27	**Arts, Design, Entertainment, Sports and Media**	2	1.332 (0.183)	3	3	3	2	3	6	3
15	**Computer and Mathematical**	3	1.274 (0.165)	1	4	1	6	12	3	4
19	**Life, Physical, and Social Science**	4	1.235 (0.322)	6	2	5	4	11	4	9
55	**Military Specific**	5	1.233 (0.212)	4	10	6	20	23	1	2
13	**Business and Financial Operations**	6	1.198 (0.252)	5	7	2	5	13	5	5
33	**Protective Service**	7	1.180 (0.235)	20	8	9	3	2	7	6
25	**Education, Training and Library**	8	1.110 (0.395)	14	9	10	7	6	9	8
21	**Community and Social Services**	9	1.102 (0.158)	7	5	14	12	4	8	11
43	**Office and Administrative Support**	10	1.072 (0.193)	10	12	7	10	9	12	10
29	**Practitioners and Technical**	11	1.061 (0.234)	11	14	8	9	5	10	17
11	**Management**	12	1.037 (0.352)	8	15	12	11	14	11	7
35	**Food Preparation and Serving**	13	0.972 (0.088)	17	13	15	13	8	17	12
39	**Personal Care and Service**	14	0.965 (0.317)	16	11	20	19	7	15	13
17	**Architecture and Engineering**	15	0.955 (0.318)	9	16	18	16	18	13	16
53	**Transportation and Material Moving**	16	0.946 (0.288)	13	6	19	14	10	22	14
31	**Healthcare Support**	17	0.922 (0.110)	15	18	22	8	16	18	15
41	**Sales and Related**	18	0.903 (0.179)	12	17	11	15	17	14	19
37	**Grounds Cleaning and Maintenance**	19	0.872 (0.204)	18	20	21	21	15	16	18
49	**Installation, Maintenance and Repair**	20	0.811 (0.149)	19	21	17	17	21	20	21
47	**Construction and Extraction**	21	0.764 (0.240)	21	19	23	22	20	19	20
51	**Production**	22	0.756 (0.232)	23	22	13	18	19	21	23
45	**Farming, Fishing, and Forestry**	23	0.638 (0.434)	22	23	16	23	22	23	22

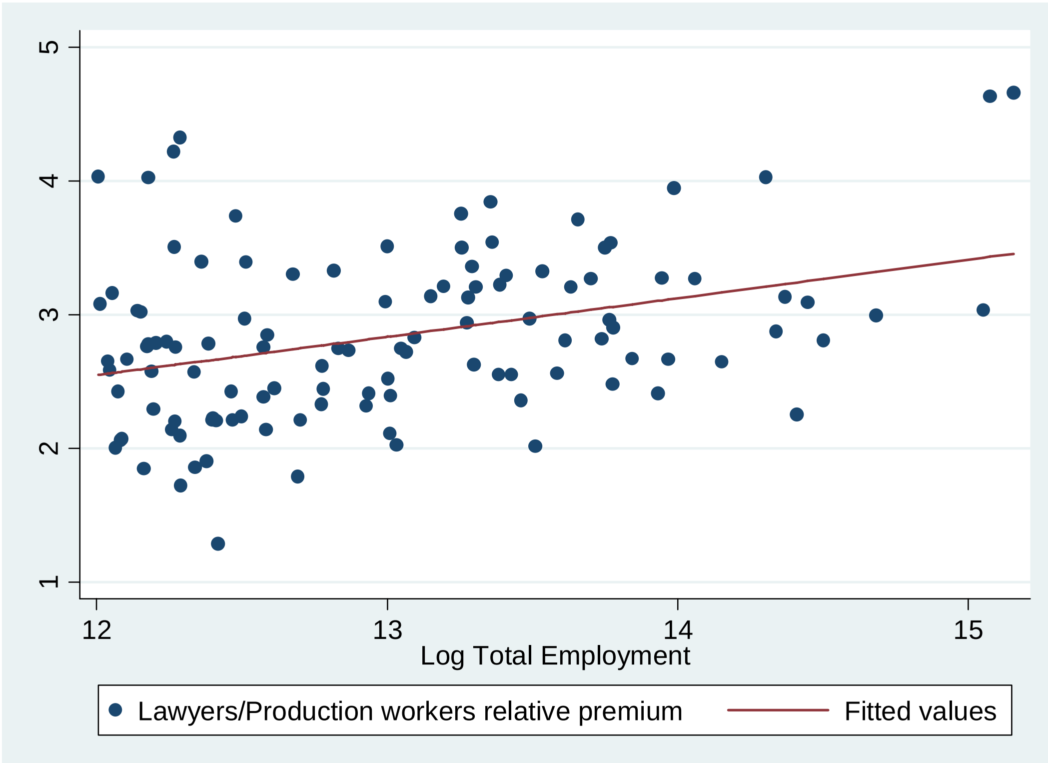
Notes: Standard errors in parenthesis.

Table 4

Dep.Var. log Wage	(1)	(2)	(3)	(4)	(5)	(6)
K × 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)			
						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 parenthesis. * significant at 10% level, ** significant ant 5% level, ***significant at 1% level. Authors' calculations using 5% Sample of 2000 Census from IPUMS. Columns 1-3 use a 30% random sample; columns 4-5 use a 5% random sample.

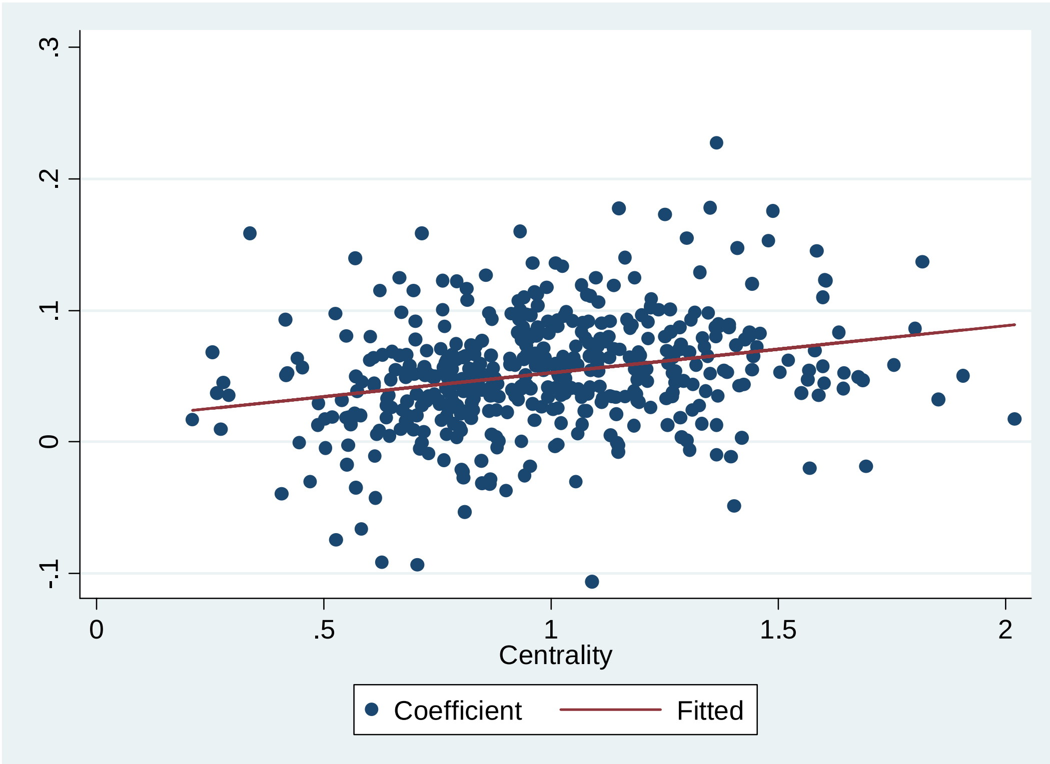
Figure 1



Title: Lawyers/Production workers relative premium and log of total employment

Notes: Authors' calculations using 5% Sample of the US 2000 Census from the Integrated Public Use Microdata Series.

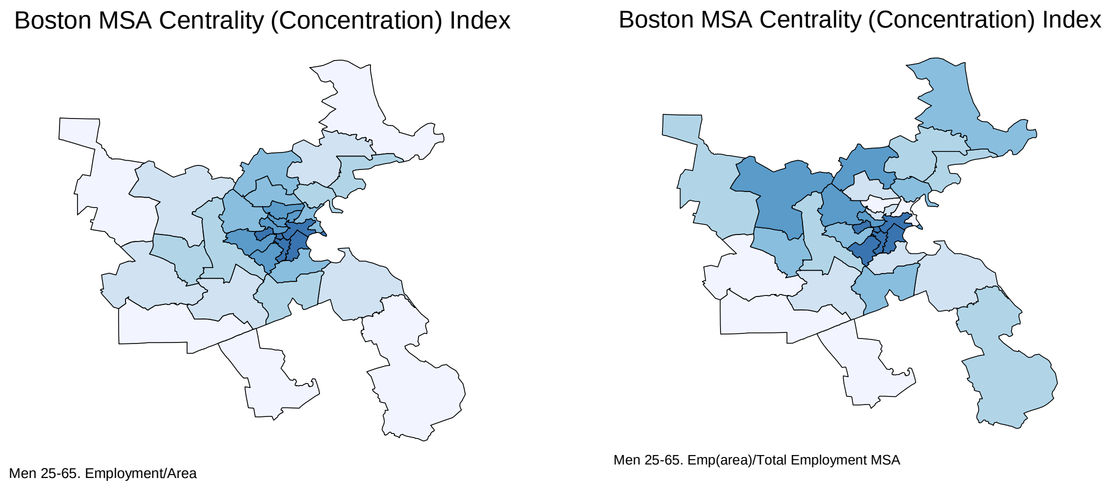
Figure 2



Title: City size premiums and centrality (log of employment)

Notes: Authors' calculations using 5% Sample of the US 2000 Census from the Integrated Public Use Microdata Series.

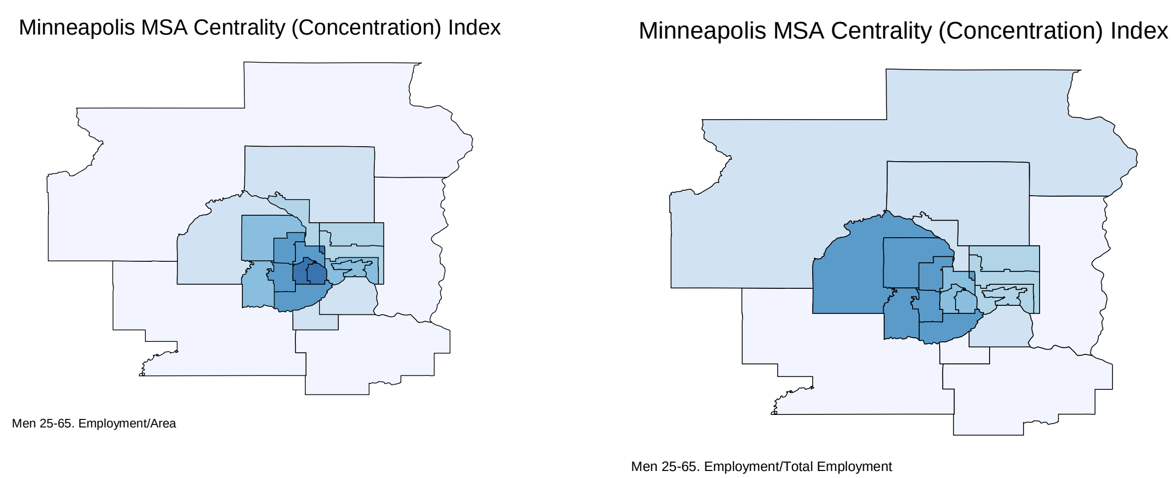
Figure 3



Title: Concentration indexes, Boston

Notes: Authors' calculations using 5% Sample of the US 2000 Census from the Integrated Public Use Microdata Series.

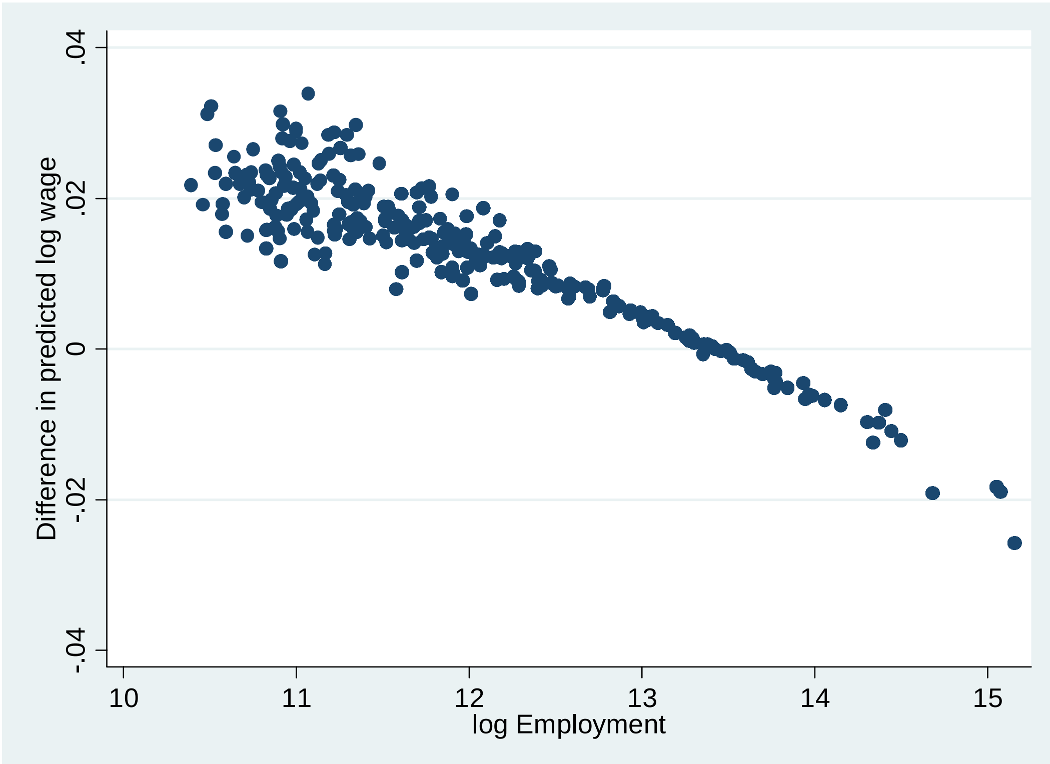
Figure 4



Title: Concentration indexes, Minneapolis

Notes: Authors' calculations using 5% Sample of the US 2000 Census from the Integrated Public Use Microdata Series.

Figure 5



Title: Predicted difference in teachers salary

Notes: Authors' calculations using 5% Sample of the US 2000 Census from the Integrated Public Use Microdata Series.