Equalizing wage differentials

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1 Preliminaries

Rosen (1986) provides a (very helpful, even if slightly dated) overview of equalizing differentials. The core idea of equalizing differences dates back to Chapter X of Adam Smith's *The Wealth of Nations*, where Smith noted: *"The whole of the advantages and disadvantages of the different employments of labour and stock must, in the same neighbourhood, be either perfectly equal or continually tending to equality."*

Why is this an important model? Rosen (1986) argues that the theory of equalizing differentials can make a legitimate claim to be *the* fundamental (long-run) market equilibrium construct in labor economics; equalizing differentials is also a central model in urban economics. Empirically, the model has been extremely useful in understanding and interpreting the structure of wages, and for making inferences about preferences and technology from observed wage data.

One reason we are interested in estimating equalizing differentials is that we often would like to know the value of non-market goods – which by definition aren't priced. Estimates of the value of many non-market goods are extremely policy-relevant. As one example, estimates of the equalizing differential for mortality risks associated with on-the-job risk exposure can provide evidence on how individuals trade off earnings with risk, and can be developed into estimates of the value of a statistical life. Because a variety of government policies involve balancing increased costs with risk reduction, these value of statistical life estimates are directly applicable in a variety of policy settings.

As a second concrete example - and to give some historical context for this literature - I want to briefly discuss what is perhaps the first rigorous analytical treatment of equalizing differentials: *Income from Independent Professional Practice*, a 1954 NBER text by Milton

Friedman and Simon Kuznets.[1] This book was Friedman's dissertation, with was published with Kuznets (his adviser). The text is a detailed study of the income structure of five professions (medicine, dentistry, law, certified public accountancy, and consulting engineering). Following on Smith's idea stated above - that the "whole of the advantages and disadvantages" of different occupations would continually tend toward equality for persons with similar ability, persistent differences in pecuniary returns would compensate for differences in training, the attractiveness of the work, the risks involved, etc. - Friedman and Kuznets argue that actual differences in income are a combination of such 'equalizing' differences, temporary differences mid-adjustment to changing economic conditions, and "persistent hinderances to the free choice of occupation." What hinderances? The authors note that hinderances could arise from the "requirement of relatively rare abilities," or they may be introduced by society.

All of that language is somewhat talking around the (very controversial) conclusion that Friedman and Kuznets arrive at in their analysis. The case study they focus on is a comparison of incomes of physicians and dentists. One version of their research question is: *"What factors explain the large and seemingly persistent difference between the average incomes of physicians and dentists living in the same community and in practice the same number of years?"* (p.123). The authors argue that the two professions require somewhat similar abilities and training. Yet four times as many persons applied annually for admission to American medical schools as for admission to American dental schools; the authors argue that on the basis of these figures alone one can conclude that the observed difference in incomes is apparently greater than the 'equilibrium' difference. But from there they ask how much of the ~ 32 percent difference in average incomes can be explained by "factors connected with the free and moderately rational choice of profession by prospective entrants" and how much to the "greater difficulty of entry into medicine." Specifically, they investigate whether differences in length of training, variability of income, nonpecuniary factors (such as "prestige"), or demand can explain this income gap. They conclude instead that the divergence between the observed and 'equilibrium' difference is primarily attributable to the greater difficulty of entry into medicine than into dentistry - not because of differences in required 'innate ability,' but rather because of a deliberate set of decisions by the American Medical Association (AMA) to artificially limit the number of licensed physicians in order to increase doctors' earnings.

From today's perspective, it's hard to appreciate how controversial this assertion was at the time; the publication of the book was delayed for several years due to objections from an NBER board member. Controversies over occupational licensing continue today, for everything from doctors to hairdressers.[2] While it is difficult to draw firm conclusions from tabulations of descriptive statistics like those presented by Friedman and Kuznets, the types of data they presented was incredibly influential in spurring subsequent researchers to think about whether the distribution of incomes we observed is consistent with the compensating differentials we would expect to see in a market economy, or whether other factors (such as barriers to entry)

[1] This text is available on the NBER website: http://www.nber.org/books/frie54-1.

[2] NPR's *Planet Money* had an interesting story covering the latter example: http://www.npr.org/blogs/money/2012/06/22/155596305/episode-381-why-its-illegal-to-braid-hair-without-a-license.

must be at play.

2 Theory of equalizing differences (Rosen, 1974)

The classic reference on the theory of equalizing differences is Rosen (1974). Here, I'm going to focus on a simplified version of the model presented in Rosen's 1986 *Handbook of Labor Economics* chapter (Rosen, 1986).

2.1 Rosen (1986): Binary case

As in 'standard' models, prices in this model adjust to achieve market equilibrium. However, whereas in standard models the identity of the traders is immaterial, here the question of "which workers work for which firms" matters because equilibrium serves a matching or sorting function that allocates specific workers to specific firms.

Labor market transactions are viewed as tied sales in which the worker simultaneously sells (rents) the services of her labor and buys the attributes of her job; likewise, employers simultaneously buy the services and characteristics of workers and sell the attributes of jobs offered to the market. The wage paid in equilibrium is therefore the sum of two transactions: one for labor services, and another for job attributes. In this sense, the labor market can be viewed as an implicit market in job and worker attributes.

Both the theory and applications of equalizing differences are based on the assumption of perfect information on both sides of the market. Given perfect information, firms and workers are capable of making decisions that are privately optimal, and their choices generate supply and demand for each type of job.

Rosen (1986) focuses on a binary case with two types of jobs: "clean" jobs ($D = 0$, no airborne particulates) and "dirty" jobs ($D = 1$, some airborne particulates). Wages w_0 and w_1 are paid to workers in each type of job. Assume that workers are productively homogenous, and differ only in their preference for D.

2.1.1 Preferences, opportunities, and worker choices

Workers have preferences over two types of consumption goods: market consumption C (purchased with money) and job type D. Worker preferences are represented by a utility function $U = U(C, D)$ where $U_C > 0$ and $U_D \leq 0$. For a given value of C, assume that $U(C, 0) \geq U(C, 1)$ - implying that $D = 1$ is not preferred to $D = 0$, other things equal.

Let C_0 denote market consumption when $D = 0$. Given C_0, let C^* denote the consumption level required to achieve the same utility with a $D = 1$ job as C_0 guarantees with a $D = 0$ job: $U(C^*, 1) = U(C_0, 0)$. Given that $D = 1$ is not preferred to $D = 0$, $C^* \geq C_0$.

Define $Z = C^* - C_0$ to be the compensating differential for $D = 1$ compared to $D = 0$ - that is, the additional consumption necessary to make the worker indifferent between the two types of jobs.

In Figure 12.1, the disamenity D is on the x-axis while the level of market consumption C is on the y-axis. Clean jobs offer $(w_0, 0)$ while dirty jobs offer $(w_1, 1)$.[3] Workers may also be endowed with unearned income y. The vertical distance cb represents Z - the compensating difference (relative to w_0) paid to workers who accept jobs with $D = 1$. Note that this utility curve is drawn for an inframarginal worker: she would be willing to work a $D = 1$ job at a wage premium of $Z = ab$, but the market clearing wage w_1 is the vertical distance $cb > ab$.

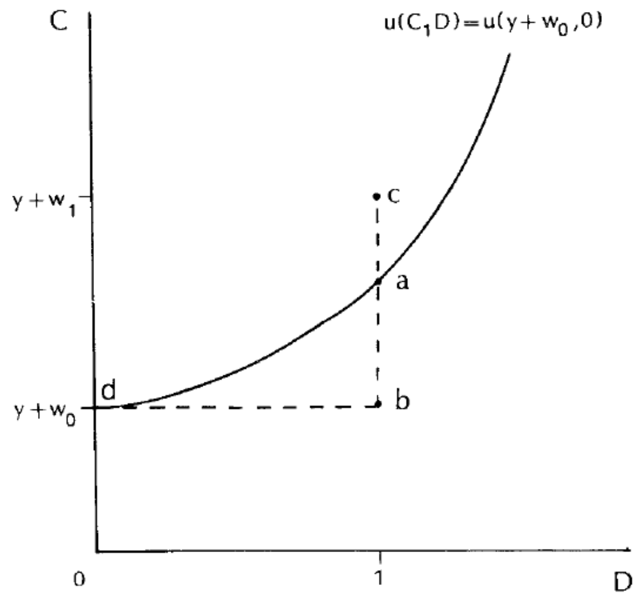

Figure 12.1

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The market equalizing wage differential is $\Delta w = w_1 - w_0$. Workers choose job type to maximize utility: workers choose $D = 1$ if $\Delta w > Z$ and choose $D = 0$ if $\Delta w < Z$ (workers are indifferent if $\Delta w = Z$, so can choose by a coin flip).

2.1.2 Market supply

Given the size of the labor force choosing between $D = 0$ and $D = 1$, relative market supply conditions are completely characterized by calculating the number of workers for whom $\Delta w > Z$ and for whom $\Delta w < Z$. Note that Δw is the same for all workers, whereas Z is a personal taste variable that varies across individuals. Workers maximize utility given Δw and their Z.

Let $Z \sim G(Z)$, so that $g(Z)$ is the density function of Z in the population of workers. Define L_1^s to be the fraction of workers applying to jobs with $D = 1$ (that is, the fraction of workers with $\Delta w > Z$), and L_0^s to be the fraction of workers applying to jobs with $D = 0$ (that is, the fraction of workers with $\Delta w < Z$). Then we have:

[3] Note that Rosen writes this as $U(C, D)$ even though in Figure 12.1, D is on the x-axis and C is on the y-axis.

$$L_1^s = \int_0^{\Delta w} g(Z)dZ \quad = \quad G(\Delta w) \tag{1}$$

$$L_0^s = \int_{\Delta w}^{\infty} g(Z)dZ \quad = \quad 1 - G(\Delta w) \tag{2}$$

Figure 12.2 illustrates L_1^s and L_0^s for a given value of Δw. Left of Δw, workers choose $D = 1$ jobs; right of Δw, workers choose $D = 0$ jobs.

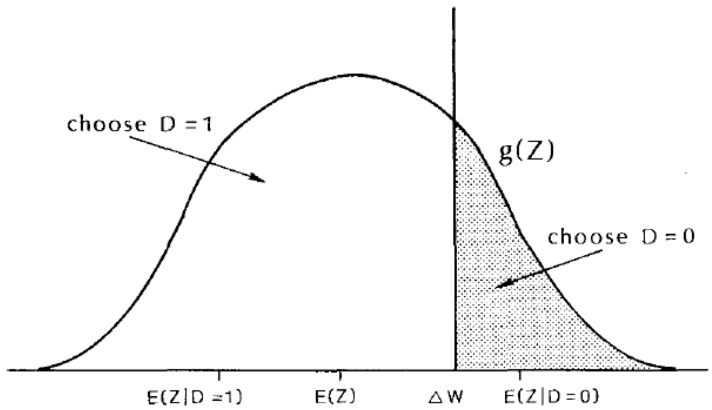


Figure 12.2

2.1.3 Technology, opportunities, and firm choices

Firms sell a good x (output) to the market; normalize the price of x to be 1. D is produced as a by-product of the production of x (for example, the production of steel x involves smoke D). Firms can use resources to reduce D - for example, purchasing cleaner capital equipment. Note that D must be productive for it ever to be observed in the market.

Let the production technology have the following form:

$$x = a_1 L \text{ if } D = 1 \tag{3}$$

$$x = a_0 L \text{ if } D = 0 \tag{4}$$

Define $B = a_1 - a_0$. Restricting $B > 0$ requires that D be productive: the efficiency of labor in x production is larger when resources are not used to clean up the work environment. B represents the marginal cost per worker of producing clean worksites, denominated in terms of forgone output. The marginal labor cost per worker of providing clean jobs is Δw. In choosing their production technology, firms thus compare B with Δw.

2.1.4 Market demand

Take firm size as exogenous. Firms differ in B, the marginal cost per worker of producing clean worksites. Let $B \sim F(B)$, so that $f(B)$ is the density function of B in the population of firms.

Firms choose $D = 1$ if $B > \Delta w$ and choose $D = 0$ if $B < \Delta w$. Define L_1^d to be the fraction of firms demanding workers in jobs with $D = 1$ (that is, the fraction of firms with $B > \Delta w$), and L_0^d to be the fraction of firms demanding workers in jobs with $D = 0$ (that is, the fraction of firms with $B < \Delta w$). Then we have:

$$L_1^d = \int_{\Delta w}^{\infty} f(B)dB \quad = \quad 1 - F(\Delta w) \tag{5}$$

$$L_0^d = \int_{0}^{\Delta w} f(B)dB \quad = \quad F(\Delta w) \tag{6}$$

Figure 12.3 illustrates L_1^d and L_0^d for a given value of Δw. Left of Δw, firms choose $D = 0$ jobs; right of Δw, firms choose $D = 1$ jobs.

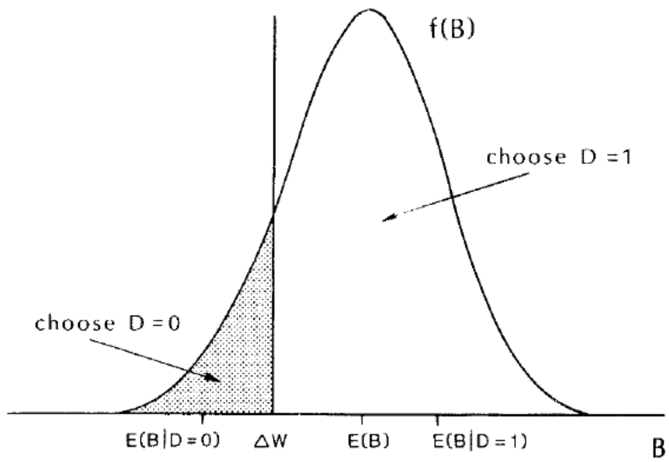


Figure 12.3

2.1.5 Market equilibrium and selection

Market equilibrium is defined by equality of supply and demand for workers in each type of job: wages w_0 and w_1 must adjust so that the number of workers seeking positions in each type of job equals the number of positions to be filled. That is, Δw adjusts so that $L_1^s = L_1^d$ (or, equivalently, $L_0^s = L_0^d$). The equilibrium wage differential Δw^* thus solves $G(\Delta w^*) = 1 - F(\Delta w^*)$.

Workers and firms are systematically matched in market equilibrium: workers in $D = 1$ jobs have the smallest distaste for D, and firms offering $D = 1$ jobs have the largest costs of cleaning up their work environment. This produces negative assortative matching in equilibrium: workers with larger Z values are systematically found in firms with smaller B values, and vice versa. This can be formally stated as:

$$E(Z|D = 0) \quad > \quad E(Z) \tag{7}$$

$$E(Z|D = 1) \quad < \quad E(Z) \tag{8}$$

$$E(B|D = 0) \quad < \quad E(B) \tag{9}$$

$$E(B|D = 1) \quad > \quad E(B) \tag{10}$$

Importantly, the market wage difference Δw is only telling us about the preferences of the *marginal* individual. We can define the term "rent" as - for a given individual - the difference between the reservation wage and the actual wage. Using this definition of rent, we can say that the market allocation may generate significant rents in the sense of the excess return relative to what would be required to change an individual's decision. In Figure 12-2, the average person choosing $D = 1$ is far from indifferent, and would keep the same job choice even if Δw changed substantially. Writing out the definition of rent as the difference between the reservation wage and the actual wage, we can note that for the average individual choosing $D = 1$, the average rent is $\Delta w - E(Z|D = 1)$.

2.2 Rosen (1986): Normally distributed case

As an example, we can work through the case where Z is normally distributed in the worker population. Write $Z = \bar{Z} + \nu$, where $\bar{Z}$ is the mean value of Z and $\nu \sim N(0, \sigma^2)$. As above, workers choose $D = 1$ if $\Delta w \geq Z$, implying that the share n_1 of workers found in $D = 1$ jobs is:

$$
\begin{aligned}
n_1 &= \Pr(Z \leq \Delta w) && (11)\\
&= \Pr(\bar{Z} + \nu \leq \Delta w) && (12)\\
&= \Pr(\nu \leq \Delta w - \bar{Z}) && (13)\\
&= \Pr\left(\frac{\nu}{\sigma} \leq \frac{\Delta w - \bar{Z}}{\sigma}\right) && (14)\\
&= \Phi\left(\frac{\Delta w - \bar{Z}}{\sigma}\right) && (15)
\end{aligned}
$$

In words, the share of workers found in $D = 1$ jobs at the relative wage Δw is the cumulative standard normal evaluated at $\frac{\Delta w - \bar{Z}}{\sigma}$. Differentiating this expression for n_1 with respect to Δw and converting to an elasticity by multiplying by $\frac{\Delta w}{n_1}$ gives:

$$
\begin{aligned}
\epsilon_1 &= \frac{\Delta w}{n_1} \frac{\partial n_1}{\partial(\Delta w)} && (16)\\
&= \frac{\Delta w}{\Phi\left(\frac{\Delta w - \bar{Z}}{\sigma}\right)} \phi\left(\frac{\Delta w - \bar{Z}}{\sigma}\right) \frac{1}{\sigma} && (17)\\
&= \frac{\Delta w}{\sigma} \left[\frac{\phi\left(\frac{\Delta w - Z}{\sigma}\right)}{\Phi\left(\frac{\Delta w - \bar{Z}}{\sigma}\right)}\right] && (18)
\end{aligned}
$$

Rosen derives an expression for the average value of Z among all workers found on $D = 1$ jobs. To derive his equations, we need to apply some properties of the standard normal distribution along the same lines as we used in our Roy model lecture notes. Specifically, if the standardized normal is truncated from above but not below (*e.g.* $E(z|z < a)$ where $z \sim N(0, 1)$), then $E(x)$ simplifies to $\frac{-\phi(b)}{\Phi(b)}$. Using this, we can calculate the average value of Z among all workers found on $D = 1$ jobs as follows:

$$
\begin{aligned}
E(Z|D=1) &= E(\bar{Z}+\nu|\bar{Z}+\nu \leq \Delta w) && (19)\\
&= \bar{Z}+E(\nu|\nu \leq \Delta w-\bar{Z}) && (20)\\
&= \bar{Z}+\sigma E\left(\frac{\nu}{\sigma}|\frac{\nu}{\sigma} \leq \frac{\Delta w-\bar{Z}}{\sigma}\right) && (21)\\
&= \bar{Z}-\sigma\left[\frac{\phi\left(\frac{\Delta w-\bar{Z}}{\sigma}\right)}{\Phi\left(\frac{\Delta w-\bar{Z}}{\sigma}\right)}\right] && (22)
\end{aligned}
$$

Define a "selection bias" term S_1 to be the difference between the unconditional mean of Z and the conditional mean $E(Z|D=1)$; S_1 is a measure of the extent to which preferences Z of people found on $D=1$ jobs differ from the average preferences among workers in the population. We can derive an expression for S_1 as:

$$
\begin{aligned}
S_1 &= \bar{Z}-E(Z|D=1) && (23)\\
&= \sigma\left[\frac{\phi\left(\frac{\Delta w-Z}{\sigma}\right)}{\Phi\left(\frac{\Delta w-\bar{Z}}{\sigma}\right)}\right] && (24)
\end{aligned}
$$

Above, we defined rents as excess returns relative to what would be required to change an individual's decision. The average rent accruing to individuals choosing $D=1$ jobs is then:

$$
\begin{aligned}
R_1 &= \Delta w-E(Z|D=1) && (25)\\
&= \Delta w-\bar{Z}+\sigma\left[\frac{\phi\left(\frac{\Delta w-Z}{\sigma}\right)}{\Phi\left(\frac{\Delta w-\bar{Z}}{\sigma}\right)}\right] && (26)\\
&= \Delta w-\bar{Z}+S_1 && (27)
\end{aligned}
$$

The average rent among $D=1$ workers is thus increasing in Δw and in the variance of preferences. Note that as the variance in preferences σ^2 goes to 0, R_1 goes to zero: with no heterogeneity, there are no inframarginal workers, implying there are no rents. More generally, the average rent is a function of σ, and thus depends on the distribution of preferences.

2.3 Rosen (1974): Continuous case

The binary choice model illustrates the key issues that arise in models of equalizing differentials. Rosen (1974) presents a more general version of the model incorporating a continuous measure D of disamenity - say, parts per million of particulates as a continuous measure of pollution. The main insight is to point out that the market-clearing equilibrium $W(D)$ wage-amenities locus is determined by the distributions of workers' tastes and producers' costs. Rosen refers to the Θ curves as bid functions (a formulation that had been and continues to be widely used in urban economics), and to the Φ curves as offer functions.

Rosen's theoretical framework has been extremely influential, but the identification approach proposed in his original paper was heavily criticized. Kahn and Lang (1988) and Ekeland, Heckman and Nesheim (2004) discuss some of the major issues that have been raised; Bartik (1987) and Epple (1987) provide additional in-depth discussions. A variety of other econometric issues also arise when estimating compensating differentials; we'll discuss these more below.

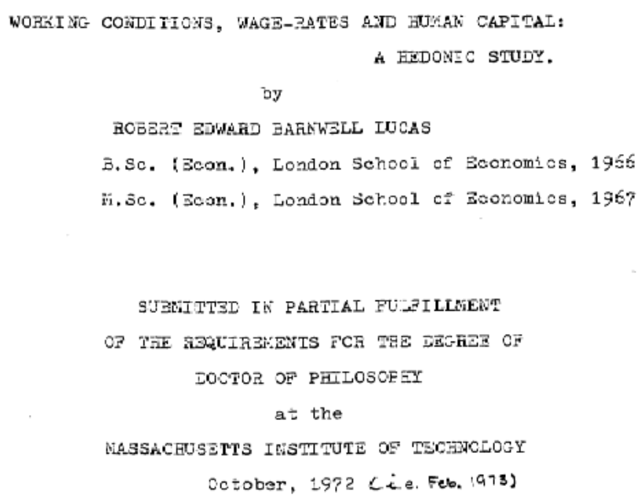
3 Estimating compensating differentials

There has been a tremendous amount of interest in empirically measuring compensating differentials for at least two reasons: first, as a test of this theoretical model; and second, because in many contexts estimates of compensating differentials are quite policy-relevant.

3.1 Version 1.0: Cross-section estimates of compensating differentials

As best I know, Lucas (1977) was the first paper to use a data source that subsequently became central to this literature: the *Dictionary of Occupational Titles*. The introduction of this paper has a great opening anecdote from Adam Smith's observation that public hangmen received higher wages for their "obnoxious task."

The work underlying this paper was part of his 1973 PhD dissertation at MIT, supervised by Frank Fisher.


WORKING CONDITIONS, WAGE-RATES AND HUMAN CAPITAL:
A HEDONIC STUDY.

by

ROBERT EDWARD BARNWELL LUCAS

B.Sc. (Econ.), London School of Economics, 1966

M.Sc. (Econ.), London School of Economics, 1967

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
at the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
October, 1972 (i.e. Feb. 1973)

At the time Lucas wrote this paper, the *DOT* data described occupational attributes for over 14,000 jobs - whether the job requires working in high temperatures, dust or fumes, high noise levels, hazardous conditions, the level of strength required, the length of vocational preparation required, whether the job is repetitive, whether the job requires making judgements, etc.

Lucas combined this *DOT* data with the *Survey of Economic Opportunity* (*SEO*) data on hourly earnings in order to estimate cross-sectional regressions of how wages varied with job characteristics. That is, his goal was to investigate how wages vary with indicators of the quality of working life by including these job characteristics in standard wage equations.

Reading the paper, you can get the sense that combining these two data sources wasn't easy. The *SEO* data didn't use the *DOT* classification system for occupations, but rather used the US 1960 five-digit Census classification scheme (with 294 categories). Lucas was able to use a cross-walk compiled by the US Department of Labor to match these two types of codes. This highlights a useful general theme: before embarking on a month-long (or many-month long!) effort to generate a cross-walk file, try to ascertain that no such cross-walk exists!

Rosen's cross-sectional specification regresses log wages on a piecewise linear function for age, an indicator for union status, and a series of job characteristics. The results are presented in Table 1. Lucas notes that the union wage premium (which he and others had documented in earlier work) persists after conditioning on these job attributes. Jobs requiring significant vocational preparation (denoted SVP in the table) are associated with a wage differential on the order of 25 percent. Although some of the coefficients for other job characteristics are of the expected sign - for example, repetitive work appears to be compensated ("Repetitive") - others are not: jobs requiring physical strength are generally associated with lower (not higher) wages ("Nonsedentary"), which Lucas notes *"suggests the omission of some skill associated with sedentary job holders."*

Table 1—Estimated Hedonic Wage Equations

	White Males			Black Males			White Females			Black Females		
Schooling	0–8	9–11	12	0–8	9–11	12	0–8	9–11	12	0–8	9–11	12
Constant	.470	.765	.819	−.111	.427	.284	.350	.603	.413	.353	.245	.287
	(.106)	(.086)	(.076)	(.176)	(.149)	(.115)	(.160)	(.119)	(.070)	(.278)	(.129)	(.095)
Age 14	−.570	−.819	−.690	−.469	−.573	−.390	−.183	−.380	−.310	−.380	−.237	−.343
	(.057)	(.042)	(.050)	(.067)	(.054)	(.079)	(.097)	(.070)	(.047)	(.123)	(.063)	(.072)
25	−.101	−.136	−.127	−.123	−.186	−.064	−.064	−.048	−.037	−.032	−.077	−.168
	(.038)	(.035)	(.026)	(.042)	(.048)	(.052)	(.076)	(.073)	(.035)	(.061)	(.054)	(.053)
99	−.687	−1.162	−.772	−.754	−1.143	−1.474	−.979	−1.371	−.423	−.208	−.257	−.700
	(.118)	(.191)	(.170)	(.162)	(.411)	(.573)	(.209)	(.359)	(.216)	(.180)	(.357)	(.475)
Union member	.299	.239	.160	.447	.268	.253	.262	.218	.208	.324	.235	.125
	(.022)	(.021)	(.017)	(.027)	(.029)	(.030)	(.051)	(.055)	(.032)	(.060)	(.050)	(.042)
SVP	.344	.228	.335	.336	.197	.335	.246	.020	.166	.201	.322	.433
	(.059)	(.057)	(.065)	(.056)	(.062)	(.062)	(.071)	(.077)	(.053)	(.071)	(.056)	(.052)
GED	.423	.245	.241	.444	.325	.139	.382	.285	.315	.128	.150	.319
	(.050)	(.046)	(.039)	(.067)	(.070)	(.068)	(.132)	(.103)	(.047)	(.148)	(.097)	(.075)
Supervise	.151	.227	.152	.184	.159	−.128	−.440	−.185	−.067	.019	−.348	.045
	(.086)	(.068)	(.053)	(.162)	(.154)	(.208)	(.342)	(.245)	(.194)	(.344)	(.257)	(.201)
Nonsedentary	−.260	−.138	−.170	.055	−.055	.275	−.504	−.398	−.188	−.610	−.217	−.282
	(.092)	(.068)	(.038)	(.172)	(.135)	(.080)	(.139)	(.089)	(.031)	(.272)	(.111)	(.064)
Repetitive	.296	.119	.103	.450	.264	.077	.400	.274	.223	.152	.110	.256
	(.045)	(.045)	(.043)	(.046)	(.056)	(.059)	(.082)	(.080)	(.049)	(.069)	(.065)	(.071)
Physical	.133	.100	.068	.109	.128	−.077	.149	.198	.033	.377	.121	.195
conditions	(.039)	(.035)	(.028)	(.047)	(.048)	(.051)	(.075)	(.079)	(.054)	(.070)	(.061)	(.066)
Degrees of freedom	1602	1758	2699	1625	956	757	735	990	2020	1038	809	826
Sum squared residuals	264.9	258.4	392.2	326.6	143.1	101.1	203.9	337.9	351.2	246.9	134.6	125.4
Residual variance	.165	.147	.145	.201	.150	.134	.278	.341	.174	.238	.166	.152
R^2	.374	.461	.199	.330	.319	.165	.233	.149	.144	.146	.152	.230

3.2 Version 2.0: Panel estimates of compensating differentials

In 1980, Brown (1980) reviewed the cross-sectional evidence of the type presented by Lucas and concluded there was surprisingly limited support for the theory of equalizing wage differentials: "The overall pattern that emerges...is one of mixed results: some clear support for the theory but an uncomfortable number of exceptions. Among the studies that fail to find equalizing differences, the most common explanation is the omission of important worker abilities, biasing the coefficients of job characteristics." (See Brown's Table 1 for a summary of references and estimates.)

The goal of the Brown paper was to move beyond these cross-sectional estimates to develop "a more appropriate test of the theory." He notes that the focus of the Rosen model is on choices made by individuals with given personal characteristics (X) among jobs with different wages (w) and non-wage attributes (Z). In order to attract labor of a given quality, an employer offering jobs that are hazardous or otherwise undesirable must pay higher wages than employers offering jobs with more desired nonwage characteristics. Individuals face a set of jobs with differing combinations of w and Z and chooses among these jobs to maximize utility.

Let larger values of Z - a vector of non-wage attributes - represent less desired jobs, where "less desired" reflects the preferences of the marginal individual. The empirical goal is to relate log wages to non-wage job characteristics, conditioning on X's that isolate "similar workers" in terms of productivity, to test the theoretical prediction that $\frac{\delta w}{\delta Z_j} > 0$ for all j.

However, we will likely have some unobserved individual productivity attributes, such as (say) unmeasured ability A_i. The true equation would therefore be:

$$ln(w_i) = \alpha + \beta X_i + \gamma Z_i + \delta A_i + u_i \tag{28}$$

We expect, based on the Rosen framework, that worse job characteristics should be associated with higher wages, so that $\gamma > 0$. We can also assume by construction that higher ability A_i is associated with higher wages, so that $\delta > 0$. If workers with higher ability use some of their higher earnings capacity to "purchase" better working conditions, then $cov(Z_i, A_i) < 0$. We would thus expect the estimate of γ to be biased downwards. As noted above, the cross-sectional empirical estimates suggest this direction of bias may be a problem, because many estimates of compensating differentials are "wrong-signed" (negative). Hwang et al. (1992) assess how much unobserved productivity biases estimates of compensating wage differentials, and conclude that these biases may be large.

Brown (1980)'s insight was that some progress can be made on this issue to the extent that most of the omitted variables are fixed within individuals over time, in which case longitudinal data (an individual fixed effects model) can be used to control for unobserved individual differences in productivity. He uses the NLS Young Men's survey, combined with the same DOT data used by Lucas, to estimate how earnings change when job characteristics change, conditional on individual-level fixed effects. Of course, some determinants of earnings capacity do change over time: age, work experience, job training, marital status, etc. The hope is that controlling for individual fixed effects reduces the omitted variables bias problem even if it does not eliminate it.

In terms of his regression specifications, in addition to year fixed effects (to capture e.g. the effect of price inflation on wages) Brown includes variables for human capital investment (company training, part-time school courses, and "other"), cumulative work experience, tenure with current employer, three measures of unionization, marital status, three geographic controls, a measure of involuntary job separation, and a measure of health. He first shows four specifications (Columns 1-4) that include these controls in addition to a 'standard' set of individual covariates: e.g. race, SES, schooling; he then shows these same specifications replacing individual covariates with individual fixed effects. Columns 1-4 differ based on the job characteristics they include.

Table II presents Brown's results, which still give many "wrong-signed" estimates relative to what is predicted by the theory. In particular, including individual fixed effects does not result in a marked improvement in the correspondence between these coefficients and *a priori* predictions. He concludes: *"The hypothesis that the inconsistent support for the theory of equalizing differences that characterized previous studies was due to the omission of important dimensions of worker quality was not supported by the data."*

TABLE II

ESTIMATES OF EQUATION (1)

Variable	Mean (st. dev.)	1	2	3	4	5	6	7	8
Constant	1.00	5.71,	5.66	5.71	5.68				
	(0.00)	(0.127)	(0.126)	(0.126)	(0.125)				
Year = 1967	0.143	−0.013	−0.015	−0.007	−0.009	0.003	0.003	0.004	0.004
	(0.350)	(0.023)	(0.022)	(0.022)	(0.022)	(0.013)	(0.013)	(0.013)	(0.013)
Year = 1968	0.143	0.012	0.009	0.026	0.023	0.035*	0.035*	0.036*	0.036*
	(0.350)	(0.033)	(0.032)	(0.032)	(0.032)	(0.018)	(0.018)	(0.018)	(0.018)
Year = 1969	0.143	0.013	0.006	0.031	0.025	0.035	0.034	0.035	0.035
	(0.350)	(0.045)	(0.045)	(0.044)	(0.044)	(0.024)	(0.024)	(0.024)	(0.024)
Year = 1970	0.143	−0.011	−0.022	0.014	0.005	0.018	0.017	0.019	0.018
	(0.350)	(0.058)	(0.057)	(0.057)	(0.057)	(0.031)	(0.031)	(0.031)	(0.031)
Year = 1971	0.143	−0.049	−0.061	−0.019	−0.029	−0.020	−0.021	−0.020	−0.021
	(0.350)	(0.071)	(0.070)	(0.070)	(0.070)	(0.038)	(0.038)	(0.038)	(0.038)
Year = 1973	0.143	−0.071	−0.090	−0.027	−0.043	−0.042	−0.043	−0.041	−0.043
	(0.350)	(0.098)	(0.097)	(0.097)	(0.097)	(0.053)	(0.053)	(0.053)	(0.053)
Cum company train school	0.078	−0.003	−0.003	−0.005	−0.006	−0.001	−0.001	0.000	−0.001
	(0.467)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Cum part-time school	0.100	0.035*	0.036*	0.033*	0.034*	0.026	0.026	0.026	0.026
	(0.368)	(0.014)	(0.014)	(0.014)	(0.014)	(0.016)	(0.016)	(0.016)	(0.016)
Cum other school	0.096	0.049*	0.047*	0.043*	0.042*	−0.007	−0.008	−0.008	−0.009
	(0.459)	(0.011)	(0.011)	(0.011)	(0.011)	(0.013)	(0.013)	(0.013)	(0.013)
Cum work exper. since 1965	3.91	0.103*	0.105*	0.096*	0.097*	0.101*	0.102*	0.102*	0.102*
	(2.17)	(0.014)	(0.014)	(0.014)	(0.014)	(0.008)	(0.008)	(0.008)	(0.008)
Years tenure current job	3.06	0.000	0.001	0.001	0.002	0.006*	0.006*	0.006*	0.006*
	(2.85)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)

(continued)

TABLE II

(cont'd.)

Variable	Mean (st. dev.)	1	2	3	4	5	6	7	8
Prob resp covered by union	0.378	0.130*	0.126*	0.134*	0.132*	0.081*	0.080*	0.080*	0.080*
	(0.448)	(0.013)	(0.013)	(0.013)	(0.013)	(0.016)	(0.016)	(0.016)	(0.016)
Union coverage, office	0.015	0.274*	0.332	0.233*	0.271*	0.178*	0.201*	0.176*	0.210*
	(0.073)	(0.074)	(0.073)	(0.074)	(0.073)	(0.076)	(0.074)	(0.076)	(0.074)
Union coverage, nonoffice	0.396	0.223*	0.178*	0.207*	0.172*	0.200*	0.190*	0.203*	0.190*
	(0.326)	(0.023)	(0.022)	(0.023)	(0.021)	(0.027)	(0.026)	(0.027)	(0.026)
Currently married	0.750	0.132*	0.133*	0.129*	0.130*	0.065*	0.065*	0.064*	0.064*
	(0.433)	(0.012)	(0.012)	(0.012)	(0.012)	(0.013)	(0.013)	(0.013)	(0.013)
Job in SMSA	0.678	0.135*	0.135*	0.135*	0.135*	0.105*	0.105*	0.104*	0.104*
	(0.467)	(0.011)	(0.011)	(0.011)	(0.011)	(0.020)	(0.020)	(0.020)	(0.020)
Residence in South	0.440	−0.016*	−0.107*	−0.107*	−0.109*	−0.003	−0.002	−0.004	−0.002
	(0.496)	(0.012)	(0.012)	(0.012)	(0.012)	(0.045)	(0.045)	(0.045)	(0.045)
Residence in West	0.095	0.034	0.031	0.040*	0.038*	0.135*	0.138*	0.133*	0.137*
	(0.293)	(0.018)	(0.018)	(0.018)	(0.018)	(0.064)	(0.064)	(0.064)	(0.064)
Cum layoff + discharge	0.439	0.001	0.000	0.002	0.002	0.013	0.013	0.011	0.012
	(0.888)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)
Health limits work	0.069	−0.021	−0.022	−0.020	−0.022	−0.009	−0.010	−0.007	−0.009
	(0.253)	(0.020)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
Race = White	0.760	0.125*	0.128*	0.110*	0.111*				
	(0.427)	(0.014)	(0.014)	(0.014)	(0.014)				
Knowledge of World of Work	33.9	0.0053*	0.0055*	0.0051*	0.0053*				
	(8.50)	(0.0008)	(0.0008)	(0.0008)	(0.0008)				
SES Index	91.3	0.0016*	0.0017*	0.0016*	0.0016*				
	(20.9)	(0.0003)	(0.0003)	(0.0003)	(0.0003)				
Cum experience in 1965	3.07	0.012*	0.011*	0.012*	0.011*				
	(2.34)	(0.002)	(0.002)	(0.002)	(0.002)				
Years schooling completed	11.0	0.031*	0.032*	0.031*	0.031*				
	(2.00)	(0.004)	(0.004)	(0.004)	(0.004)				
Cum military training	0.150	0.005	0.006	0.005	0.006				
	(0.635)	(0.008)	(0.008)	(0.008)	(0.008)				
Government worker	0.091	−0.074*	−0.091*	−0.060*	−0.071*	−0.076*	−0.080*	−0.074*	−0.079*
	(0.287)	(0.019)	(0.019)	(0.019)	(0.019)	(0.024)	(0.024)	(0.024)	(0.024)
Sup/wages in industry	0.110	0.010	0.185	0.050	0.178	0.170	0.223	0.161	0.217
	(0.051)	(0.119)	(0.117)	(0.118)	(0.116)	(0.163)	(0.161)	(0.163)	(0.161)
Time now in company train	0.008	−0.009	0.003	0.003	0.012	−0.036	−0.033	−0.032	−0.029
	(0.067)	(0.079)	(0.079)	(0.078)	(0.078)	(0.061)	(0.061)	(0.061)	(0.061)
Time now in part-time sch	0.008	−0.357*	−0.360*	−0.361*	−0.360*	−0.200*	−0.204*	−0.205*	−0.209*
	(0.058)	(0.088)	(0.088)	(0.087)	(0.087)	(0.071)	(0.071)	(0.071)	(0.071)
Time now in other training	0.008	−0.193*	−0.181*	−0.191*	−0.182*	−0.116	−0.112	−0.117	−0.113
	(0.063)	(0.082)	(0.082)	(0.082)	(0.081)	(0.065)	(0.065)	(0.065)	(0.065)
Occupation = apprentice	0.018	−0.007	−0.005	−0.028	−0.030	−0.098*	−0.097*	−0.098*	−0.098*
	(0.132)	(0.039)	(0.039)	(0.039)	(0.039)	(0.034)	(0.034)	(0.034)	(0.034)
Repetitive work	0.395	−0.137*	−0.143*	−0.036	−0.029	−0.049*	−0.050*	−0.056*	−0.048*
	(0.361)	(0.015)	(0.016)	(0.024)	(0.023)	(0.016)	(0.017)	(0.025)	(0.025)
Work under stress	0.067	0.041	−0.005	−0.012	−0.043	0.028	0.027	−0.019	−0.017
	(0.176)	(0.031)	(0.032)	(0.033)	(0.034)	(0.040)	(0.040)	(0.043)	(0.043)
Physical strength required	0.188	−0.006	−0.036	0.030	0.011	−0.028	−0.036	−0.009	−0.018
	(0.252)	(0.023)	(0.022)	(0.023)	(0.022)	(0.025)	(0.024)	(0.026)	(0.025)
Bad working conditions	0.561	−0.067*		−0.044*		−0.031		−0.037	
	(0.353)	(0.018)		(0.019)		(0.020)		(0.021)	
Deaths/1,000 manyears	0.225		0.060*		0.057*		0.009		0.007
	(0.448)		(0.012)		(0.012)		(0.012)		(0.012)
Ln (usual hours)	3.77	−0.375*	−0.381*	−0.368*	−0.369*	−0.254*	−0.255*	−0.254*	−0.255*
	(0.198)	(0.031)	(0.030)	(0.030)	(0.030)	(0.028)	(0.028)	(0.028)	(0.028)
Part-time worker	0.028	−0.095*	−0.105*	−0.087*	−0.089*	−0.052	−0.053	−0.053	−0.053
	(0.164)	(0.037)	(0.037)	(0.037)	(0.036)	(0.032)	(0.032)	(0.032)	(0.032)
Low GED requirement	0.584			−0.044	−0.067*			0.044	0.033
	(0.387)			(0.024)	(0.022)			(0.024)	(0.024)
Low SVP requirement	0.158			−0.212*	−0.204*			−0.075*	−0.075*
	(0.222)			(0.030)	(0.030)			(0.030)	(0.030)
Standard error of estimate		0.277	0.276	0.274	0.274	0.202	0.202	0.202	0.202
R-squared		0.635	0.636	0.641	0.643	0.833	0.833	0.834	0.834
Number of observations		3,290	3,290	3,290	3,290	3,290	3,290	3,290	3,290

* = Statistically significant at the 0.05 level.

Brown summarizes his results as: *"The impacts of the intercepts on the coefficients of job characteristics vary considerably, and there is no marked improvement in the correspondence between these coefficients and* a priori *predictions."* In his conclusion, Brown discusses several potential explanations for his results:

1. Labor markets are not as competitive as the theory of equalizing differences assumes. Are the assumptions of perfect information profit- and utility-maximization that underlie Rosen's model too strong? Brown argues that considerably weaker assumptions still imply such differences.

2. Marginal workers' tastes may differ from those assumed in *a priori* sign of the coefficients. Brown argues this is plausible for the physical strength variable, but less so for other variables. That is, while some workers may wish to avoid physical labor, other workers may prefer physical labor to sitting at a desk all day, in which case jobs requiring physical strength may not be unpleasant for the marginal worker and no equalizing difference may be required. However, this story seems unlikely to hold for alternative factors like the risk of death on the job (!).

3. Job characteristics are not well-measured. This is likely a huge issue. Use of the *DOT* data introduces measurement error because workers are assigned the mean job characteristics for her occupation/industry, not the characteristics specific to her job. Some other studies use self-reported survey measures of job characteristics, but these measures are thought to be quite unreliable (see the discussion in Rosen (1986)). If this measurement error is accurately characterized as classical measurement error, this will bias γ towards zero. Note that this measurement error problem will likely be exacerbated in individual fixed effects models.

4. Omitted variables - both individual- and job-level - may be biasing the estimates. Brown highlights freedom to work overtime as one potentially important omitted job characteristic. In terms of individual-level characteristics, an individual fixed effects specification solves some problems but introduces others: why do some individuals change jobs but not others? Could job changes be driven by changes in unobserved individual-level productivity? Are job changes driven by poor "matches," which could induce bias?

5. Testing the model on twenty-somethings is inappropriate. He limits the sample to older workers, and the estimates don't change remarkably, so this doesn't appear to be a major issue.

The Murphy and Topel (1987) chapter on the syllabus applies an individual fixed effects approach to explore inter-industry wage differentials.

Several big-picture issues come up in Version 1.0 and Version 2.0 of this empirical literature on equalizing wage differentials. First, unobserved factors are a huge issue. The Brown paper attempts to address unobserved individual-specific factor by controlling for individual factors that don't vary over time, but obviously this approach doesn't address all omitted variables bias concerns and it introduces several new problems: measurement error may be exacerbated in first-differenced or fixed effect models (you'll work through this on a problem set), and endogenous mobility may introduce problems. Second, measurement error in the job characteristics data is likely a major issue. Both of these concerns motivated researchers to search for alternative methodologies to estimating compensating wage differentials.

3.3 Version 3.0: Estimating compensating differentials using policy variation

The cross-section and panel methods for estimating compensating differentials produced a variety of non-sensical and "wrong-signed" estimates on how workers value non-wage job characteristics. While we previously focused on risks such as risk of death on the job, a different type of non-wage job characteristic is a non-wage benefit such as health insurance. Do workers value health insurance one-for-one for wages? What about other types of benefits, such as workers' compensation insurance? In a cross-section, these questions are hard to answer for the standard omitted variables reasons. To address those challenges, this literature moved towards examining mandated employer-provided benefits - such as for health insurance and workers' compensation - as a source of quasi-experimental variation.

3.3.1 Employer-mandated benefits: Summers (1989)

A famous *American Economic Review Papers & Proceedings* article by Larry Summers (Summers, 1989) laid out a framework clarifying how to think about the incidence and welfare costs of employer-mandated benefits. Importantly, Summers showed that mandated benefits may have different effects on equilibrium wages and employment than do taxes: the labor market equilibrium depends on how workers value the benefits.

Let labor demand be $L_d = f_d(W + C)$ where W is the wage and C is the cost of the mandated health insurance. Let labor supply be $L_s = f_s(W + \alpha C)$, where αC is the monetary value that employers place on health insurance. In equilibrium, $L_s = L_d$. Letting η^d denote the labor demand elasticity and η^s denote the labor supply elasticity, you can show by totally differentiating the equilibrium conditions that if $\alpha = 1$ (that is, if employees value benefits as if they were wages) then wages fall by the full cost of the mandated benefit, while there is no change in employment. The problem set will have you work through a version of this model. In public finance, this is referred to as the tax-benefit linkage. Importantly, there could be no deadweight loss from this if workers fully value the benefit.

This Summers framework spurred an empirical literature analyzing how wages and employment respond to changes in mandated employer-provided benefits. Gruber and Krueger (1991) analyze the impact of increases in mandated workers' compensation insurance, finding evidence of substantial wage offsets; Fishback and Kantor (1995) analyze the initial passage of workers' compensation laws, finding similar evidence. Gruber (1994) analyzed the impact of state and federal requirements mandating insurance coverage of maternity care, finding evidence of wage offsets among workers who would have generated the increased insurance costs. Gruber (1997) analyzes the incidence of payroll tax changes, incorporating the Summers (1989) insight that payroll tax revenues are often used to finance programs that benefit only workers - such as Social Security or workers compensation - implying a tax/benefit linkage with payroll taxes. Gruber finds that reductions in payroll taxes appear to have been fully passed along to workers, with little effect on employment levels; although this is consistent with full employee valuation of benefits, Gruber is unable to test this possibility against competing explanations.

3.3.2 Workers' compensation: Fishback and Kantor (1995)

I want to discuss the Fishback and Kantor (1995) paper as an example, which is an excellent example of how economic history can again be a good laboratory for labor economics research questions. State-level workers' compensation was introduced in the 1910s. Fishback and Kantor give a useful discussion of the political economy of these policies: social reformers widely touted the introduction of these programs as bonuses to workers, whereas the literature cited above suggests that the de facto redistribution of income caused by employer-mandated benefits may differ in important ways from that view.

In order to investigate the extent to which these mandated benefits were passed along to workers in the form of lower wage rates, Fishback and Kantor collect pre- and post- wage data from three (relatively dangerous) industries: coal mining, lumber milling, and the unionized building trades.

Table 2. Table 2 of their paper shows the variation in expected workers' compensation as a percentage of annual earnings by state, 1910-1923. The main thing to note is the staggered timing, although adoption was relatively rapid. Within a year, the level of the benefits also varied across states. Not the most easy-to-interpret way of illustrating this variation, but it can be hard to summarize this type of variation.

TABLE II

Expected Benefits under Workers' Compensation as a Percentage of Annual Earnings by State, 1910–1923

State	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923
AK	.	.	.	.	.	2.02	1.85	1.67	1.44	1.30	1.13	1.20	1.24	1.54
AL	.	.	.	.	.	.	.	.	.	.	1.05	1.15	1.20	1.12
AR	.	.	.	.	.	.	.	.	.	.	.	.	.	.
AZ	.	.	.	1.67	1.67	1.68	1.63	1.58	1.42	1.30	1.16	2.18	2.24	2.12
CA	.	1.71	1.71	1.69	1.51	1.51	1.53	1.53	1.62	1.68	1.56	1.65	1.65	1.65
CO	.	.	.	.	.	0.96	0.88	0.87	0.72	0.83	0.68	0.74	0.78	0.90
CT	.	.	.	.	1.20	1.26	1.26	1.26	1.25	1.42	1.31	1.36	1.39	1.35
DE	.	.	.	.	.	.	.	.	0.97	1.31	1.18	1.30	1.33	1.26
FL	.	.	.	.	.	.	.	.	.	.	.	.	.	.
GA	.	.	.	.	.	.	.	.	.	.	.	0.84	1.20	1.15
HI	.	.	.	.	.	1.42	1.42	1.55	1.55	1.48	1.35	1.46	1.49	1.46
IA	.	.	.	.	1.17	1.17	1.17	1.17	0.97	1.25	1.03	1.13	1.18	1.10
ID	.	.	.	.	.	.	.	.	1.41	1.23	1.00	1.41	1.47	1.37
IL	.	.	1.48	1.42	1.42	1.42	1.42	1.54	1.42	1.40	1.14	1.29	1.35	1.25
IN	.	.	.	.	.	1.28	1.28	1.40	1.40	1.30	1.06	1.17	1.22	1.14
KS	.	.	1.23	1.23	1.23	1.23	1.23	1.40	1.40	1.24	1.02	1.12	1.17	1.09
KY	.	.	.	.	.	.	1.57	1.45	1.32	1.14	1.07	1.17	1.23	1.14
LA	.	.	.	.	.	1.17	1.28	1.28	1.40	1.40	1.35	1.43	1.53	1.45
MA	.	.	1.65	1.64	2.16	2.17	2.04	1.96	1.67	1.53	1.26	1.38	1.63	1.57
MD	.	.	1.27	1.27	1.32	1.32	1.32	1.32	1.23	1.08	1.42	1.56	1.63	1.52
ME	.	.	.	.	.	.	1.25	1.25	1.06	1.33	1.12	1.38	1.44	1.35
MI	.	.	1.14	1.14	1.14	1.14	1.14	1.14	0.95	1.27	1.04	1.17	1.23	1.14
MN	.	.	.	1.17	1.17	1.22	1.22	1.48	1.23	1.38	1.13	1.54	1.61	1.74
MO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MS	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MT	.	.	.	.	.	1.30	1.30	1.30	1.08	1.17	0.96	1.06	1.11	1.03
NC	.	.	.	.	.	.	.	.	.	.	.	.	.	.
ND	.	.	.	.	.	.	.	.	.	2.82	2.57	2.76	2.81	2.71
NE	.	.	.	1.28	1.28	1.28	1.28	1.68	1.39	1.51	1.24	1.36	1.42	1.32
NH	.	.	1.21	1.21	1.21	1.21	1.21	1.21	1.05	0.95	0.82	0.88	0.91	1.20
NJ	.	1.14	1.14	1.14	1.14	1.14	1.14	1.14	0.99	1.08	0.89	0.97	1.02	1.26
NM	.	.	.	.	.	.	.	0.99	0.91	1.03	0.88	1.01	1.05	0.99
NV	.	.	.	1.43	1.54	1.66	1.65	1.65	2.19	2.48	2.14	2.29	2.37	2.25
NY	1.73	1.73	1.71	1.80	2.33	2.33	2.32	2.32	2.26	2.12	1.86	2.00	2.32	2.27
OH	.	.	1.61	1.70	1.77	1.77	1.77	1.61	1.50	1.40	1.15	1.32	1.38	1.28
OK	.	.	.	.	.	0.72	0.72	0.72	0.60	0.95	0.95	0.95	0.95	0.99
OR	.	.	.	.	2.40	2.40	2.23	1.99	1.65	1.50	1.23	1.60	1.64	1.57
PA	.	.	.	.	.	.	1.21	1.21	1.01	0.87	0.84	0.92	0.97	0.90
RI	.	.	1.24	1.24	1.24	1.24	1.24	1.47	1.27	1.13	1.12	1.26	1.28	1.25
SC	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SD	.	.	.	.	.	.	.	1.17	1.10	1.01	0.84	1.06	1.10	1.03
TN	.	.	.	.	.	.	.	.	.	1.03	0.85	0.93	0.97	1.20
TX	.	.	.	1.84	1.84	1.84	1.82	1.61	1.61	1.46	1.19	1.31	1.37	1.61
UT	.	.	.	.	.	.	.	1.38	1.30	1.57	1.29	1.41	1.48	1.38
VA	.	.	.	.	.	.	.	.	.	0.84	0.82	0.90	0.95	0.88

TABLE II

(CONTINUED)

State	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923
VT	.	.	.	.	.	1.02	1.02	1.01	1.09	1.01	0.93	1.11	1.13	1.09
WA	.	2.14	2.07	2.01	2.00	2.01	1.81	1.69	1.40	1.75	1.43	1.58	1.65	1.74
WI	.	1.94	1.88	1.56	1.55	1.56	1.41	1.55	1.29	1.12	0.92	1.72	1.79	1.81
WV	.	.	.	1.67	1.67	1.66	1.54	1.41	1.17	1.36	1.11	1.22	1.28	1.64
WY	.	.	.	.	.	1.04	0.93	1.03	0.85	0.96	0.93	1.22	1.27	1.18

A period implies that no workers' compensation law was in effect during that year. Some states enacted the laws in the year prior to its going into effect. The expected benefits are as of the end of the year. Maryland in 1910 had a set of benefits for coal miners in Garrett and Alleghany Counties, which were not as lucrative as the ones the state introduced in 1914. Montana also experimented with workers' compensation on a limited basis in 1909, but the law was declared unconstitutional. Kentucky in 1914 passed a law that was declared unconstitutional before it went into effect. New York's law in 1910 reflects the elective law. A compulsory law for more dangerous industries was enacted in 1910, but it was declared unconstitutional.

Sources. Using the national average manufacturing weekly wage for each state, we calculated expected benefits following the procedures described in the Appendix. We then divided the expected benefits by annual earnings (52 times the weekly wage) and multiplied by 100. We derived the weekly wage by multiplying weekly hours (series D765, p. 168) and hourly earnings (series D766, p. 168) for the period 1900 to 1926 [U. S. Census Bureau 1975, p. 168].

For each of their three industries, they estimate regressions of the following form for occupation i in state j in year t:

$$w_{ijt} = \beta_0 + D_{ijt}\beta_1 + B_{ijt}\beta_2 + WT_{ijt}\beta_3 + A_{ijt}\beta_4 + U_{ijt}\beta_5 + o_i + s_j + y_t + e_{ijt} \quad (29)$$

where w_{ijt} is the real hourly wage, D_{ijt} are measures of product market fluctuations and worker productivity (average), B_{ijt} are postaccident benefits, WT_{ijt} are working time restrictions, A_{ijt} is the accident rate, U_{ijt} are measures of strikes and union strength, s_j are state fixed effects, y_t are year fixed effects, and o_i are occupation fixed effects. If we were estimating this today, we would show specifications both with and without these controls, and show some timing/event studies around the time of the policy change (but those graphs were not the 'norm' at the time this paper was written).

Table 3. The estimates are shown in Table 3. Looking at a 0/1 variable for any workers' compensation, we see wage declines that are statistically significant for coal mining and lumber mills. The measure of compensation generosity pains a similar picture; given that a coefficient of -1 implies that workers fully paid for increases in the expected benefits, Fishback and Kantor can't reject full pass through for the non-unionized industries. These wage offsets are roughly similar in magnitude to Gruber and Krueger (1991)'s analysis of workers compensation in more recent data. Interestingly, wage offsets are much smaller for the unionized sector.

TABLE III

FIXED-EFFECTS WEIGHTED LEAST SQUARES WAGE REGRESSIONS
(DEPENDENT VARIABLE IS HOURLY WAGE IN 1890–1899 CENTS)

Variable	Coal mining hourly wage workers		Lumber mill workers		Unionized building trades	
Workers' compensation dummy	−0.603 (3.67)		−0.335 (2.62)		−0.124 (0.604)	
Expected present value of accident compensation[a]		−1.72 (4.14)		−1.04 (2.11)		0.020 (0.031)
Limits on working time[b]	0.053 (0.138)	0.264 (0.704)	−0.359 (18.5)	−0.362 (18.6)	−0.843 (22.7)	−0.843 (22.7)
Product price or other product demand index[c]	8.46 (17.7)	8.35 (17.5)	0.277 (6.68)	0.286 (6.95)	0.044 (5.02)	0.044 (5.01)
Productivity measure[d]	6.43 (3.46)	7.66 (4.12)	0.387 (2.44)	0.386 (2.43)		
Fatal accidents per million man-hours	−0.029 (0.505)	−0.005 (0.086)				
Paid-up membership in the United Mine Workers of America as a percentage of employment	0.111 (0.161)	0.317 (0.469)				
Strike days per employee	0.010 (2.56)	0.012 (3.16)				
Strike days per employee lagged one year	−0.006 (2.28)	−0.005 (2.20)				
Strike days per employee in states other than state *j*	0.072 (4.00)	0.079 (4.42)				
Intercept	3.40 (2.52)	2.57 (1.91)	37.4 (30.5)	37.6 (29.5)	77.1 (45.7)	77.0 (45.5)
Occupation dummies	9 of 10	9 of 10	9 of 10	9 of 10	12 of 13	12 of 13
Geography dummies	22 of 23 states	22 of 23 states	22 of 23 states	22 of 23 states	76 of 77 cities	76 of 77 cities

TABLE III
(CONTINUED)

Variable	Coal mining hourly wage workers		Lumber mill workers		Unionized building trades	
Year dummies	included	included	included	included	included	included
N	2690	2690	1236	1236	6563	6563

Absolute values of t-statistics are in parentheses below coefficient estimates. Coefficients of the occupation, year, and geography dummies are available from the authors. F-tests reject the hypothesis that the coefficients of these dummy variables are simultaneously zero. The mean of the wage is 27.7 (standard deviation of 28) in the coal sample, 20.4 (10.4) in the lumber sample, and 37.3 (9.4) in the building trades sample. Since the data use information based on means from states with different sample sizes, we used weighted least squares. In the coal estimation the square root of the number of coal workers in the state was used as the weight. In the lumber sample, the square root of the number of sampled workers is used as the weight. The building trades data did not report sample size, so White's [1980] method is used to adjust the standard errors. Using White's standard error correction for the coal and lumber regressions does not change the basic results reported above.

Sources. Average hourly earnings in the coal industry are from Fisher and Bezanson [1932, pp. 254–89, 296–325]. The union variable is the percentage of workers with paid-up membership in the UMWA reported in U. S. Coal Commission [1925, p. 1052], with straight-line interpolations to fill years not reported. The remaining coal data were compiled from U. S. Bureau of Mines Bulletins titled, "Coal-Mine Fatalities in the year. . . ," and U. S. Geological Survey (after 1922 Bureau of Mines) publications titled, *Mineral Resources of the United States, Part II, Nonmetals,* various years. For further details on the coal sample, see Appendix B of Fishback [1992, pp. 234–41]. Wage and hours worked data for each of the lumber occupations were collected from U. S. Bureau of Labor Statistics Bulletin Numbers 129, 153, 225, 317, and 363. Lumber price and output data are reported in U. S. Department of Agriculture [1948]. The total number of lumber workers in each state was derived using a straight-line interpolation of data reported in U. S. Bureau of the Census [1913, pp. 504–05]; U. S. Bureau of the Census [1919, pp. 986–88]; and U. S. Bureau of the Census [1923, pp. 466–71]. Wage and hours worked data for each of the building occupations were collected from the following U. S. Bureau of Labor Statistics "Union Scale of Wages and Hours of Labor" Bulletins (year(s) of coverage in parentheses): *131 (1907–1912), 143 (1913), 171 (1914), 194 (1915), 214 (1916), 245 (1917), 259 (1918), 274 (1919), 286 (1920),* 302 (1921), 325 (1922), and 354 (1923). The building permit data were collected from Riggleman [1934, pp. 263–76]. All dollar values have been deflated using Paul Douglas' cost-of-living index (1890–1899 = 100), series E185 in U. S. Bureau of Commerce [1975, p. 212].

a. The expected value of accident compensation is scaled to correspond to the hourly measurement of the dependent variable. We divided the expected benefits measures by estimates of hours worked per year. For the coal sample we assumed that miners worked an average of 206.4 eight-hour days (derived from the sample). We assumed that lumber workers worked a total of 3000 hours per year and building tradesmen worked 2250 hours. The latter two estimates were calculated as the average number of hours worked per week given in the sample multiplied by 50 weeks.

b. Limits on working time in the coal industry are measured as the mean number ($\times 10^{-2}$) of days the state's mines were open in that year and the number of hours in a full-time week in the lumber and building trades industries.

c. The product price is the average price of coal at the mine mouth adjusted for inflation. The lumber price index is a weighted average (by output) of the real prices of individual species of lumber produced in each state. Product demand in the building trades is measured as the per capita value of building permits. Since these data were reported at the regional level, we matched each city observation to its particular region for the given year.

d. The productivity variable in the coal industry is total coal output divided by total man-days (number of workers multiplied by average days worked multiplied by average hours per day). Lumber productivity is calculated as the total quantity of lumber cut per lumber worker in each state ($\times 10^{-2}$).

Source: Fishback and Kantor (1995).

3.4 Version 4.0: Estimating compensating differentials using job offers

A variant of Version 2.0 - the individual fixed effects approach - which makes progress on holding unobserved individual productivity fixed is a method developed by Stern (2004). Stern's insight was that in entry-level labor markets many individuals receive multiple job offers before accepting any specific offer. Each offer is composed of a wage and a series of job characteristics. By observing individuals' accepted job relative to the wage-amenity characteristics of other jobs in their offer set, it is possible to estimate compensating differentials in a way that overcomes many of the problems inherent in the individual fixed effects approaches that rely on job changes. We will talk more about this approach in an upcoming lecture.

4 Application: Spatial equilibrium (Roback, 1982)

As an application, we are going to focus on the Roback (1982) model (sometimes referred to as the Rosen-Roback model), which is motivated by wanting to understand the implicit prices of various urban attributes. The Roback model is arguably *the* model of urban economics, and one that has been very widely applied to a range of economic questions.

4.1 Motivating facts

Roback motivates her paper by saying that a long history of (at the time) previous work had observed intercity and regional wage differences among workers with the same measured productivity (as proxied by education and experience). For example, Table 4 of Fuchs (1967) documents regional differences in wages across observably similar workers, with wages in the Southern US tending to be lower than in other regions.[4]

TABLE 4

Ratio of Actual to "Expected" Hourly Earnings, by Region, 1959

	South	Non-South	North-east	North Central	West
			(Ratio)		
White males	.90	1.03	1.02	1.03	1.05
White females	.89	1.04	1.07	1.00	1.07
Nonwhite males	.80	1.16	1.09	1.20	1.21
Nonwhite females	.79	1.21	1.30	1.16	1.19
Total	.89	1.04	1.04	1.03	1.06
			(Index of Ratio, South = 100)		
White males	100	114	113	114	117
White females	100	117	120	112	120
Nonwhite males	100	145	136	150	151
Nonwhite females	100	153	165	147	151
Total	100	117	117	116	119

Source: Tables 2 and 3.

You may look at this and think: why is it surprising that workers in different parts of the country with the "same" potential earnings (in a human capital sense) earn different wages? Surely the amenities available differ across areas, and it's not like we expect earnings to equalize across areas, we expect *utilities* to equalize across areas. My sense from the Fuchs book and the Roback paper was that that was not what people were thinking at the time – they instead saw these regional wage differences as a "puzzle." Similarly, Table 8 of Fuchs documents significant differences in wages across observably similar workers between cities of different sizes.

[4]This text is available on the NBER website: http://www.nber.org/books/fuch67-1.

TABLE 8

Ratio of Actual to "Expected" Hourly Earnings, by City Size, 1959

		Urban Places		Standard Metropolitan Statistical Areas			
	Rural	Under 10,000	10,000-99,999	Under 250,000	250,000-499,999	500,000-999,999	1,000,000 and More
South	.76	.76	.83	.89	.94	.96	1.06
Non-South	.88	.88	.94	1.00	.99	1.05	1.13
Northeast	.91	.92	.95	.96	.96	.99	1.10
North Central	.85	.85	.93	1.03	1.03	1.11	1.16
West	.91	.89	.95	1.01	1.00	1.05	1.14

My sense is that prior to Roback's analysis, most investigations of these types of regional and city-size wage differentials focused solely on the consumer side of the market without taking into account the behavior of firms. In contrast, Roback's contribution was to conceptualize the equilibrium decisions of both firms and workers. Her motivating example is the following: if workers require a compensating wage differential to live in a big, polluted, or otherwise unpleasant city, the firms in that city must have some productivity advantage that allows them to pay the higher wage. Her model applies Rosen's key insight: the implicit prices of attributes represent both the marginal valuation to consumers and the marginal cost to firms; focusing only on the consumer side will provide an incomplete picture.

The contribution of Roback's model relative to the previous literature was two-fold. First, the idea that in a spatial equilibrium both land and labor markets must clear had not previously been well-understood. Second, the factors that influence the decomposition of the implicit prices of attributes into wage gradients vs. rent gradients had not been analyzed. Intuitively, in order for utility to be equalized across locations, either wages must be lower or costs of living must be higher in more amenable locations; but in the absence of a model, it isn't clear whether utility equalization across locations should show up as wage differences, or as differences in site-specific costs of land or housing, or both. The Roback model is designed to guide our thinking on both of these issues by presenting a general equilibrium model that incorporates both mobile factors (labor) and site-specific factors (land).

The key difference between Roback's model and Rosen's model is that in Roback's model, both land and labor markets must clear. In Rosen's model, if firms are homogenous and workers are homogenous then exactly one wage-amenity bundle is offered in equilibrium. However, in Roback's spatial allocation problem people cannot all occupy the same space even if they have identical preferences; the scarcity of land gives rise to an additional constraint on the problem. Roback solves for equilibrium wages and rents.

4.2 Model

Let s index a vector of amenities that differ across cities but are constant (and fixed) within cities. The index s can include a variety of amenities - climate, pollution, crime - and is indexed such that a higher level of s is preferred by workers. Each city has a wage rate w and a price of land r. Roback focuses on the case where workers are identical and firms are identical.

Workers and firms are perfectly mobile across cities (no moving costs), but must live and work in the same city. Land is fixed, although Roback notes that this can be relaxed to an assumption that there is a rising supply price of land (for example, due to within-city transportation costs).

In the worker's decision problem, leisure is ignored and each person supplies a single unit of labor (independent of the wage rate). Conditional on any given location with a particular level of s, workers choose consumption over a composite commodity x (sold at price 1) and residential land l^c (sold at price r) subject to the budget constraint: $\max_{x,l^c} U(x, l^c; s)$ subject to $w + I = x + l^c r$, where I represents non-labor income. In spatial equilibrium, we can re-write this as an indirect utility function $V(w, r; s) = k$ for a constant k. That is, wages and rents must adjust to equalize utility in all locations - otherwise individuals would have an incentive to move. Because a higher level of s is preferred by workers, $\frac{\partial V}{\partial s} > 0$.

In the firm's decision problem, a constant returns to scale production function is assumed: $x = f(l^p, N; s)$ where l^p is land used in production and N is the total number of workers in the city. Note that this assumes that production requires physical space; it might be interesting to look at the location decisions of firms that allow employees to work remotely (or which by construction involve off-site work).

Firms minimize costs subject to the production function and sell x on the world market at a fixed price, normalized to 1. Unit costs at each location must equal the price: $C(w, r; s) = 1 = p$. The unit cost function is increasing in both factor prices. If the amenity is unproductive, then $C_s > 0$ (unproductive amenities raise the cost of production).[5] Roback's example of an unproductive amenity is "clean air," which workers value but which makes firm production more costly; her example of a productive amenity is "lack of severe snow storms," because blizzards are both costly to firms and unpleasant to consumers (definitely true based on my former life as a North Dakotan, and winter 2015 in Boston).

The indirect utility function and unit cost condition generate equilibrium levels of wages $w(s)$ and rents $r(s)$ for a given level of k, where k is determined by aggregate labor demand and aggregate labor supply. Roback illustrates the equilibrium in Figure 1.

[5] Note that this seems to be a typo in the original paper, where Roback says that if the amenity is unproductive then $C_s < 0$.

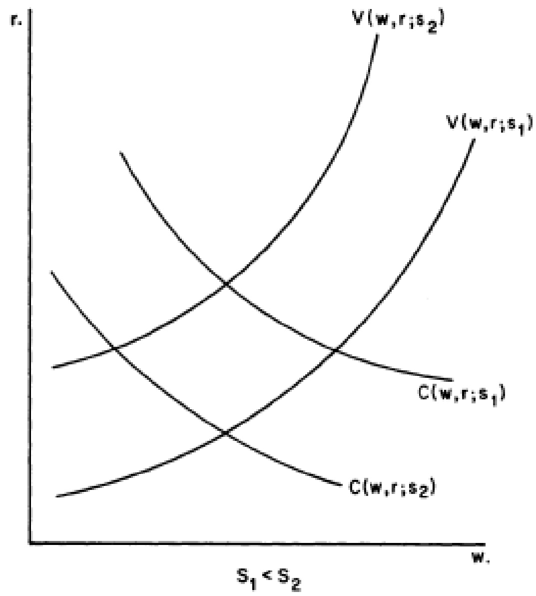


FIG. 1

In Figure 1, s is an unproductive amenity - say, clean air: workers prefer clean air but clean air raises firms' costs because they must invest in pollution abatement. Two sets of curves are drawn:

- Firm cost curves. The downward-sloping lines are combinations of wages w and rents r that equalize unit costs at a given level of s.
- Worker indirect utility curves. The upward-sloping lines are combinations of wages w and rents r that equalize indirect utility at a given level of s.

The results underlying Figure 1 can be obtained by deriving expressions for $\frac{dw}{ds}$ and $\frac{dr}{ds}$.[6] Totally differentiating the indirect utility function $V(w, r; s) = k$ gives $v_w dw + v_r dr + v_s ds = 0$. Totally differentiating the cost function $C(w, r; s) = 1 = p$ gives $c_w dw + c_r dr + c_s ds = 0$. We can combine these equations to derive the following expressions for $\frac{dw}{ds}$ and $\frac{dr}{ds}$:

$$\frac{dw}{ds} = \frac{c_s v_r - c_r v_s}{c_r v_w - c_w v_r} \tag{30}$$

$$\frac{dr}{ds} = \frac{c_w v_s - c_s v_w}{c_r v_w - c_w v_r} \tag{31}$$

The denominator is the same in both expressions: $c_r v_w - c_w v_r$. We know that $v_w > 0$, $c_r > 0$, $c_w > 0$, and $v_r < 0$; taken together, these imply $c_r v_w - c_w v_r > 0$. For $\frac{dw}{ds}$, we can sign the numerator because we know that $c_s > 0$, $v_r < 0$, $c_r > 0$, and $v_s > 0$, implying that $\frac{dw}{ds} < 0$ – wages decline as s increases. For $\frac{dr}{ds}$, the numerator can't be unambiguously signed: all four of c_w, v_s, c_s, and v_w are > 0, so the overall sign of the numerator will depend on the relative magnitude of $c_w v_s$ relative to $c_s v_w$. Hence, rents may either increase or decline as s increases.

[6] Note that in this derivation, Roback ignores elasticities of substitution because she focuses on small changes.

Thus, in locations with higher levels of unproductive amenities, wages should be lower, but the change in rents is uncertain. Intuitively, because s is unproductive, firms prefer low s locations whereas workers prefer high s locations. Because high rents discourage both firms and workers from locating in an area, worker equilibrium requires high rents in high s areas to discourage immigration, while firm equilibrium requires low rents in high s areas to induce firm location. On the other hand, low wages discourage workers and attract firms. The factor prices equalize to strike a balance between the conflicting locational preferences of firms and workers. If s were productive instead of unproductive, rents would rise whereas the change in wages would be ambiguous. Big-picture, the key take-away is the the extent to which wages vs. rents will adjust depend on whether workers, firms, both, or neither value a particular amenity.

4.3 Data

Roback analyzes the 1973 May CPS data for the 98 largest US cities, and limits the sample to men over the age of 18 who reported earnings. She uses a publication called *FHA Homes* as a source of residential site prices - specifically, average site prices per square foot. This data is only available for 83 of the 98 cities, and over-samples lower income households (because the data only includes FHA-eligible families).

4.4 Results

Table 1. Regressions of log(earnings) on city characteristics. Note the vintage table with t-statistics instead of standard errors :) The paper has notes on the data sources for these variables in Appendix B, but includes essentially zero discussion of how the covariates were chosen. Some of these are fixed area characteristics (climate variables), whereas others could be analyzed in a panel setting. She does not give much help on distinguishing which should be considered productive versus unproductive amenities (or how we might test that). It seems like more on that type of discussion would make it easier to learn something concrete from this table.

TABLE 1

COEFFICIENTS OF CITY CHARACTERISTICS FROM LOG EARNINGS REGRESSIONS IN 98 CITIES

	1	2	3	4
TCRIME 73	$.94 \times 10^{-5}$ (2.58)	$.44 \times 10^{-5}$ (1.17)	$.74 \times 10^{-5}$ (1.93)	$.86 \times 10^{-5}$ (2.21)
UR 73	$.36 \times 10^{-2}$ (1.29)	$.12 \times 10^{-2}$ (.43)	$.32 \times 10^{-2}$ (1.14)	$.27 \times 10^{-2}$ (.97)
PART 73	$.24 \times 10^{-3}$ (1.55)	$.13 \times 10^{-3}$ (.86)	$.37 \times 10^{-3}$ (2.33)	$.34 \times 10^{-3}$ (2.15)
POP 73	$.16 \times 10^{-7}$ (7.97)	$.15 \times 10^{-7}$ (7.74)	$.16 \times 10^{-7}$ (8.04)	$.16 \times 10^{-7}$ (8.11)
DENSSMSA	$.81 \times 10^{-6}$ (.29)	$.24 \times 10^{-5}$ (.86)	$.20 \times 10^{-5}$ (.73)	$.38 \times 10^{-5}$ (1.40)
GROW 6070	$.21 \times 10^{-2}$ (7.84)	$.14 \times 10^{-2}$ (5.66)	$.15 \times 10^{-2}$ (6.06)	$.17 \times 10^{-2}$ (6.47)
HDD	$.20 \times 10^{-4}$ (8.48)			
TOTSNOW		$.72 \times 10^{-3}$ (3.54)		
CLEAR			$-.64 \times 10^{-2}$ (−4.80)	
CLOUDY				$.72 \times 10^{-2}$ (5.21)
R^2	.4980	.4955	.4960	.4962
F-ratio	424.2	420.0	420.8	421.1
N = 12,001				

NOTE.—Regressions include all personal characteristics. Sample includes 98 cities; t-statistics are in parentheses (see App. for variable definitions).

Table 2. Asks what influence city attributes have on regional differences in earnings. Although there are strong regional differences in wages, once city characteristics are conditioned on these regional differences largely disappear (except for the WEST coefficient, which is still statistically significant and negative).

TABLE 2

COEFFICIENTS OF REGION DUMMIES AND CITY CHARACTERISTICS

NORTHEAST	−.0218	−.0095
	(−2.25)	(−.74)
SOUTH	−.0669	−.0138
	(−6.51)	(−.87)
WEST	−.0354	−.0579
	(−3.46)	(−3.41)
TCRIME 73		$.13 \times 10^{-4}$
		(2.82)
UR 73		$.92 \times 10^{-2}$
		(2.60)
PART 73		$.29 \times 10^{-3}$
		(1.87)
POP 73		$.16 \times 10^{-7}$
		(7.77)
DENSSMSA		$-.13 \times 10^{-5}$
		(−.42)
GROW 6070		$.23 \times 10^{-2}$
		(8.41)
HDD		$.16 \times 10^{-4}$
		(4.86)
R^2	.4900	.4986
F-ratio	479.4	384.0

NOTE.—Regressions include all personal characteristics. Sample includes all 98 cities; t-statistics are in parentheses.

Table 3. Analogous to Table 1, except the left-hand-side variable is now log(price per square foot) instead of log(earnings). As in Table 1, she does not give much help on distinguishing which should be considered productive versus unproductive amenities (or how we might test that).

TABLE 3

REGRESSIONS OF THE LOG OF AVERAGE RESIDENTIAL SITE PRICE PER SQUARE FOOT ON CITY CHARACTERISTICS

	1	2	3	4
TCRIME 73	2.5×10^{-5} (.65)	1.5×10^{-5} (.38)	-4.5×10^{-7} (−.01)	7.0×10^{-6} (.16)
UR 73	8.9×10^{-2} (3.45)	8.8×10^{-2} (3.35)	9.2×10^{-2} (3.53)	9.1×10^{-2} (3.52)
PART 73	2.2×10^{-4} (.15)	1.1×10^{-4} (.08)	-3.8×10^{-5} (−.02)	1.4×10^{-4} (.09)
POP 73	6.8×10^{-8} (1.80)	6.9×10^{-8} (1.78)	6.8×10^{-8} (1.76)	6.8×10^{-8} (1.76)
DENSSMSA	1.9×10^{-4} (3.02)	2.0×10^{-4} (3.12)	2.0×10^{-4} (3.17)	2.0×10^{-4} (3.18)
GROW 6070	1.1×10^{-2} (4.34)	1.0×10^{-2} (4.11)	9.9×10^{-3} (4.03)	1.0×10^{-2} (4.00)
HDD	3.5×10^{-5} (1.44)			
TOTSNOW		1.3×10^{-3} (.69)		
CLEAR			1.2×10^{-4} (.09)	
CLOUDY				3.2×10^{-4} (.21)
INTERCEPT	−1.73 (−5.92)	−1.54 (−5.99)	−1.44 (−6.51)	−1.53 (−3.32)
R^2	.5741	.5650	.5623	.5625
F-ratio	14.44	13.92	13.77	13.78

SOURCE.—Data are from U.S. Department of Housing and Urban Development 1973. N = 83.

Table 4. Combines coefficients from Tables 1 and 3 as well as the budget share of land in order to compute the implicit price for each attribute in percentage terms. Negative numbers indicate "bads" and positive numbers indicate "goods." Table reports marginal price of the amenity evaluated at average earnings. For example, the average person would be willing to pay \$69.55 per year for an additional clear day.

TABLE 4

IMPLICIT PRICES OF AMENITIES COMPUTED FROM TABLES 1 AND 3

	1	2	3	4
TCRIME 73 (crimes/100 population)	\$−9.25	\$ .90	\$ −8.05	\$ −9.15
UR 73 (fraction unemployed)	−5.55	20.65	−.70	5.00
PART 73 (micrograms/cubic meter)	−2.50	−1.40	−4.00	−3.70
POP 73 (10,000 persons)	−1.50	−1.40	−1.50	−1.50
DENSSMSA (100 persons/square mile)	6.30	4.90	5.35	3.35
GROW 6070 (percentage change in population)	−1.85	−11.95	−13.05	−15.2
HDD (1° F colder for one day	−.20			
TOTSNOW (inches)		−7.30		
CLEAR (days)			69.55	
CLOUDY (days)				−78.25

NOTE.—Measurement units of amenities shown under variable name. Each entry is computed using eq. (5) in the text and evaluated at mean annual earnings. $p_s^* = [k_l(d \log r/ds) - (d \log w/ds)]w$. Average annual earnings = \$10,868. Average budget share of land = .035. Negative numbers indicate disamenities, while positive numbers indicate amenities.

4.5 Take-aways

The Roback model is an incredibly important contribution in terms of providing a concrete framework for analyzing spatial equilibrium, and for thinking about whether a given amenity is likely to be capitalized into rents, wages, or both. Practically, this model has been applied to thinking about quality of life indices across cities, as well as to a variety of applications in urban and labor economics. This is a useful model to have in your toolkit.

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