Sherwin Rosen

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Abstract

This paper provides a critical survey of Sherwin Rosen's contributions to economics. I identify the ideas that influenced him and the themes—diversity and inequality—that connect his papers. The model of compensating price differentials (Rosen 1974) is his greatest hit. The more general "equalizing differences" approach was a signature feature of his research in labor economics and other fields. I also evaluate the merits of Rosen (1979), through which he receives credit for the influential Roback-Rosen model in urban economics. And several of his most influential papers substantiate my claim that Rosen was an inequality economist.

1. Introduction

Sherwin Rosen was a highly productive and influential scholar. His legacy includes major contributions to economic theory, labor economics, urban economics, and monopoly pricing. A product of Gregg Lewis's Labor Workshop, Rosen earned his Ph.D. from the University of Chicago in 1966, two years after joining the economics faculty at the University of Rochester as an assistant professor. Returning to Chicago in 1977, Rosen was a leading figure in the economics department until his death at age 62 in 2001, just two months after becoming president of the American Economics Association.

Rosen published widely and with influence. He frequently contributed to the *Journal of Political Economy*, where he published eight full papers and several shorter pieces. His hedonic prices paper (Rosen 1974) is the sixth most cited paper in the 130-year history of the *JPE* (Amiguet et al. 2017). Lazear and Rosen's (1981) tournaments paper makes the *JPE*'s top-25 list. (The citations to his eight *JPE* papers place him fifth among the top contributors to the *JPE*.) Other highly influential papers are his *Journal of Economic Theory* paper with Michael Mussa on monopoly pricing (Mussa and Rosen 1978), his *American Economic Review* papers on superstars (Rosen 1981) and incentives in sequential tournaments (Rosen 1986a), and his paper on employment hierarchies in the *Bell Journal of Economics* (Rosen 1982). Table 1 lists his most cited papers.

In this paper, I highlight the connections among his most important papers. I also identify the ideas that influenced him, connecting the dots from Adam Smith's exposition

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Table 1: Rosen's Most-Cited Papers

Rank	*Paper*	*Title*	*Citations*
1*	Rosen (*JPE*, 1974)	Hedonic Prices and Implicit Markets: Product Differentiation …	4,153
2*	Lazear and Rosen (*JPE*, 1981)	Rank-Order Tournaments as Optimum Labor Contracts	1,879
3	Mussa and Rosen (*JET*, 1978)	Monopoly and Product Quality	1,296
4*	Rosen (*AER*, 1981)	The Economics of Superstars	847
5*	Rosen (*AER*, 1986)	Prizes and Incentives in Elimination Tournaments	513
6*	Rosen (*BellJ*, 1982)	Authority, Control and the Distribution of Earnings	490
7	Rosen (volume, 1986)	The Theory of Equalizing Differences	410
8*	Willis and Rosen (*JPE*, 1979)	Education and Self-Selection	395
9*	Thaler and Rosen (vol., 1976)	The Value of Saving a Life: Evidence from the Labor Market	275
10	Rosen (volume, 1979)	Wage-Based Indexes of Urban Quality of Life	262
11	Rosen (*JEL*, 1985)	Implicit Contracts: A Survey	221
12*	Rosen (*JHR*, 1972)	Learning and Experience in the Labor Market	187
13	Nadiri and Rosen (*AER*, 1969)	Interrelated Factor Demand Functions	176
14	Topel and Rosen (*JPE*, 1988)	Housing Investment in the United States	172
15	Rosen (*REStud*, 1969)	Trade Union Power, Threat Effects and Extent of Organization	139
16	Lazear and Rosen (*JOLE*, 1990)	Male/Female Wage Differentials in Job Ladders	129
17*	Rosen (*JOLE*, 1983)	Specialization and Human Capital	111
18	Rosen (*JPE*, 1976)	A Theory of Life Earnings	95
19*	Rosen (*Economica*, 1978)	Substitution and Division of Labor	93
20	Rosen (*Econometrica*, 1968)	Short-Run Employment Variation on Class-I Railroads …	92

Notes: *Indicates that Rosen included the paper in the volume of his collected works (Rosen 2004). *Source*: Web of Science Core Collection database. Citations as of April 30, 2020.

of equalizing differences in the *Wealth of Nations*, through Milton Friedman and Simon Kuznets's impressive application of Smith's idea to the earnings of doctors, lawyers, accountants, and other independent professionals, and to Jacob Mincer's dissertation article, which advances a formal model of schooling to explain earnings inequality.

I reach several strong conclusions. First, in section 1, I show that Rosen's hedonic prices paper fails in one of its purposes—to provide an econometric method to identify the underlying structure of preferences and technologies in the context of product (or job) attributes. The model that he develops to address identification, however, has been a perennial hit. Second, through his influence on Jennifer Roback's dissertation and her 1982 *JPE* paper, Rosen deserves ample credit for a major advance in urban economics. The profession delivers this credit by continuing to cite his 1979 paper in an obscure volume. The paper, which few people have likely read, does *not* stand on its merits. Third, in section 2, I establish that Rosen was an inequality economist. A theme that connects almost all of his papers is a concern for inequality—sources of inequality in general and earnings inequality in particular. In fact, the diversity at the core of his models of equalizing differences in section 1 tightly connects to his models of inequality in section 2.

Rosen rarely used the term compensating differential. He also avoided hedonic prices, although that term features prominently in his classic *JPE* paper. He favored Smith's "equalizing differences," and this is the first evidence of Smith's strong influence on Rosen. He also viewed equalizing differences as a broader class of models than compensating differentials. For instance, Rosen distinguished the equalizing differences approach to human

capital from the efficiency-units approach. Most labor economists, reserving compensating wage differentials for analysis of job attributes, treat human capital and compensating wage differentials as distinct topics. Rosen found the concept of equalizing differences powerful in explaining how wages vary with the attributes of workers as well as jobs.

2. Equalizing Differences

The "Hedonic Prices and Implicit Markets" article in the *JPE* is Rosen's most influential paper, and it connects all his best research. Rosen took a centuries-old approach to labor markets (i.e., equalizing differences) that he and others were fruitfully applying to job and worker attributes and constructed a general model of compensating price differentials. The model advanced neoclassical economics and spawned a burst of empirical activity.

Hedonic Prices and Implicit Markets

Rosen's model of compensating price differentials provides the economics behind hedonic price regressions, justifies quality adjustments of price indexes, and establishes that product differentiation is consistent with competition. In the paper's opening paragraph, however, Rosen reveals am ancillary purpose: to identify the underlying structure of preferences and technologies in the context of differentiated products. So he lays out an econometric strategy to identify the compensated demands and supplies of attributes.

Let's see how Rosen proposed to recover the structure from a hedonic regression in the context of single attribute z.

Buyers. A consumer buys x units of an undifferentiated product and, for simplicity, one unit of a good with attribute z. Utility function $U(x, z)$ represents the buyers preferences. Two elements of opportunities are the budget set $x + p \leq y$ and the competitive price function $p = p(z)$; the price of x is $p_x = 1$, and y is income. Replace x in the utility function with $y - p$ from the budget constraint to reduce the dimension of the problem.

The buyer chooses a product variety (z, p) to maximize utility $U(y - p, z)$ subject to the competitive pricing of the differentiated product $p = p(z)$. At an interior solution, the first-order conditions require that the marginal rate of substitution between the attribute and the quantity of the other good equal the marginal price of the differentiated good.

$$\frac{U_z}{U_x} = p'(z) \tag{1}$$

along the price function. Figure 1 displays a buyer's optimal choice at point A as the tangency of the price function $p(z)$ to an indifference curve, which Rosen calls a bid function.[1]

Figure 1 also displays a second indifference curve, one from a second buyer with the same preferences but higher income. (There is a complete set of indifference curves for each income y.) If the attribute is normal, raising income raises the marginal rate of substitution at each point (z, p), and the higher income consumer buys a better variety at point B.

Sellers. A firm produces q units of the good with attribute z and sells the variety (z, p) in a competitive market with pricing function $p = p(z)$. Rosen solves the problem in two

[1] Diminishing marginal rate of substitution between x and a (i.e., quasi-concavity of U) is necessary and sufficient for concavity of the indifference curves in the z–p space

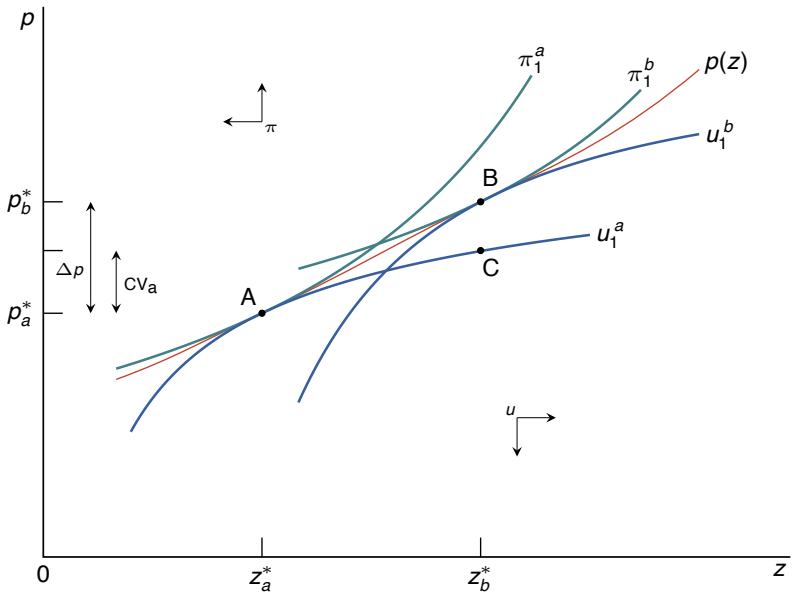

Figure 1. Compensating Price Differential

steps: first, given a value of the attribute z, the firm chooses output q to maximize profit; second, after replacing q in the profit function with the implied product supply function (given z), the firm chooses z to maximize profit. Three equations define the profit-maximizing choice. The marginal cost of quantity equals the price of the product; the marginal cost of the attribute equals its marginal price; and the price is competitive.

$$C_q(q, z) = p \tag{2a}$$

$$\frac{C_z(q, z)}{q} = p'(z) \tag{2b}$$

$$p = p(z) \tag{2c}$$

Figure 1 displays the firm's profit-maximizing design choice at point A as the tangency of the price function $p(z)$ to an iso-profit curve, which Rosen calls an offer function.[2] A firm with lower marginal cost of attribute z has flatter iso-profit curves. As point B in Figure 1 shows, such a firm sells a more z-intensive product at a higher price.

Equilibrium. The equilibrium is a price function $p(z)$ that equates quantities demanded and supplied at each value of z; that is, $p(z)$ must align the assignments of buyers (based on equation (1)) and seller (based on equation (2)). To find the equilibrium price function, we use equations (1) and (2) to transform the distributions of income (or preferences) and technologies into two distributions of z. The resulting distributions depend on $p(z)$. Then we solve for the $p(z)$ that equates the two distributions at each z. This process typically involves solving a differential equation; boundary conditions set the level of $p(z)$.

[2]Set $d\pi = 0$ to find that the implied slope of an iso-profit curve in the z–p space is $dp/dz = C_z(q(p, z), z)/q(p, z)$. An iso-profit curve is an increasing, convex function of z if marginal cost is an increasing function of z.

Regulation that places a floor on product quality is a simple application that clarifies why Rosen sought to identify the structure of preferences and technologies from observations on the price function. How much do buyers and sellers lose from a regulation that sets a floor on product quality? From Figure 1, a floor on product quality at z_b^* does not affect the type–b buyers and sellers, but it hurts type–a buyers and sellers. In fact, a type–a buyer's loss is the distance between points *B* and *C*, which is the price differential Δp minus the compensating variation CV_a. The compensating variation depends on the curvature of the indifference curve, so measuring the effect of the policy requires knowledge of the underlying preferences. The price function $p(z)$ is not enough.

Identification. Can we identify the structure of preferences or technologies from knowledge of a single price function $p(z)$? Consider the buyer's side. For any assignment of buyer to attribute z, we can rationalize that choice with a range of preferences from complements to perfect substitutes. In the figure, indifference curves with right angles (or tangent lines) at points A and B would fit the data just as well. That is, preferences with no substitutability (or perfect substitutability) between x and z fit the data as well as the true preferences displayed in the figure. Thus knowledge of the price function cannot identify the preference structure. A similar argument holds on the firm side.

So we should be skeptical of the two-step estimation strategy that Rosen proposes. The first step involves estimating the price function and calculating marginal price p' for each value of z in a single market. The second step uses these marginal prices in "a garden variety" two-stage least squares regression. (Rosen recognizes that variation in the marginal prices requires nonlinearity of the price function.) The hope is that exogenous variation in cost factors can instrument the attribute z, and the resulting variation in the price traces an indifferences curve such as u_1^a; that is, variation in p' and the instrumental variable $\hat{z}$ traces out the compensated demand function.

Two problems undermine the proposed method even in data from multiple markets. First, generating consistent estimates of $p(z)$ is challenging due to omitted variables (e.g., Brown 1980). Second, second-step estimation is even more challenging because the usual instruments are not valid (e.g., Bartik 1987; Epple 1987). In particular, the way that buyers and sellers match along the price function implies that exogenous variation from costs and technology is correlated with the residual in the compensated demand equation. Similarly, taste shifters are correlated with the residual in the attribute supply equation.

Rosen did not solve the identification problem, but the method he proposed has framed the issue for decades. Researchers continue to debate identification in a single cross section, and the debates tie closely to Rosen's model of compensating price (or wage) differentials and the two-step method (e.g., Ekeland, Heckman, and Nesheim 2004).

From Smith Through Friedman and Kuznets to Mincer and Lewis

What influenced Rosen's research on equalizing differences and his hedonic prices paper in particular? He often cited Smith (1776 [1994]), Friedman and Kuznets (1945), and Mincer (1958) (or Mincer 1974) in his papers. His use of "equalizing differences" rather than "compensating differentials" points to Smith's influence, and Smith and Friedman and Kuznets always preceded Rosen (1974) on the reading list in his graduate labor economics course. Nevertheless, Rosen does not cite these works in his *JPE* article because there he presents

a model of compensating *price* differentials. He does acknowledge the influence of discussions with Gregg Lewis and cites Lewis (1969).

Rosen worked within a modeling tradition that Adam Smith spawned in Chapter X of the *Wealth of Nations* (Smith 1776 [1994]). Smith opens the chapter "Of Wages and Profit in the Different Employments of Labor and Stock" with a manifesto.

> The whole of the advantages and disadvantages of the different employments of labour and stock must, in the same neighborhood, be either perfectly equal or continually tending to equality. If in the same neighborhood, there was any employment evidently either more or less advantageous than the rest, so many people would crowd into it in the one case, and so many would desert it in the other, that its advantages would soon return to the level of other employments. This at least would be the case in a society where things were left to follow their natural course, where there was perfect liberty, and where every man was perfectly free both to chuse what occupation he thought proper, and to change it as often as he thought proper. Every man's interest would prompt him to seek the advantageous, and to shun the disadvantageous employment. (p. 116)

In Part 1 on "Inequality arising from the Nature of the Employments themselves," Smith presents an empirically grounded model of equalizing differences: how wages vary with the attributes of jobs and workers. He identifies five factors: (1) working conditions, (2) expense of learning the trade, (3) risk of being out of work, (4) trust of those in the position, and (5) risk of failure. Factors (1) and (3) are the core of compensating wage differentials for job attributes. Smith's factors (2) and (5) are about investment in human capital. And factor (4) points to efficiency wages. All five factors are elements of equalizing differences.

Friedman and Kuznets's (1945) pathbreaking empirical analysis of the earnings of doctors, dentists, lawyers, engineers, and accountants revived Smith's equalizing differences and greatly influenced Rosen's early approach to labor markets, his classic paper on hedonic prices, and his subsequent research.[3] Echoing Smith, Friedman and Kuznets argue, "If every individual were entirely free to choose his occupation, 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, and the like. Actual differences in income are a combination of such 'equalizing' differences, temporary differences that arise from imperfect adjustment to changing economic conditions, and differences that reflect persistent hindrances to the free choice of occupation" (pp. v–vi). In Chapter 4, they use five factors to explain the income differential between medical doctors and dentists[4]: length of training, variability of income, nonpecuniary factors, barriers to rapid adjustment, and difficulty of entry.

[3]Smith's Chapter 10 had not been forgotten. Indeed, Hicks (1932) omits equalizing differences from his *Theory of Wages* on the grounds that the topic was well understood: "[F]or the general tendency for the wages of laborers of equal efficiency to become equalized in different occupations (allowance being made for other advantages or disadvantages of employment) has been a commonplace of economics since the days of Adam Smith, and little needs to be added here" (p. 3).

[4]Friedman and Kuznets (1945, pp. 133–4) include a sixth factor: the influence of demand. Their discussion distinguishes between the stock of practitioners and the flow of new entrants. In their data, medical doctors outnumber dentists by a factor of two but three and half to four times as many persons seek to become doctors

Rosen also frequently credited Mincer (1958) (and later Mincer (1974)) as a leading example of the equalizing differences approach to labor markets, although Mincer was working in the context of schooling and work experience rather than job attributes. For instance, Willis and Rosen (1979, p. S8, footnote 1) declare, "The equalizing difference model originates with Friedman and Kuznets (1945). Jacob Mincer (1974) has developed it most completely in recent years." Mincer presents a model of school choice in which the equilibrium wage-schooling relationship equalizes wealth among identical people, which is a splendid example of equalizing differences. But Mincer does not refer to equalizing differences (or compensating differentials) anywhere in his book. Nor does he reference Smith or Friedman and Kuznets.

Since Rosen's 1974 paper had a specific purpose, to identify the structures of preferences and technologies, and was set in the context of products (rather than the labor market), Rosen did not reference Smith, Friedman and Kuznets, or Mincer. But equalizing differences was an active research environment. For instance, Rees and Shultz (1970) open their study of wages in Chicago by quoting Smith on the whole of the advantages and disadvantages and remark that the *Wealth of Nations* is still the best expression of the classical theory of wage differentials. Rosen's own work on trade unions (Rosen 1969b) and learning by doing on the job (Rosen 1972) positions him within an influential approach to labor economics at the time he wrote the hedonic prices paper.

Five years before Rosen's hedonic prices paper appeared in the *JPE*, Gregg Lewis published a paper on the employer's interest in the working hours of employees in Spanish in the Peruvian journal *Cuadernos de Economia* (Lewis 1969). Lewis's paper recasts the labor supply problem with the workday or workweek as a job attribute, a now familiar application of compensating wage differentials with fatigue effects and per-worker costs driving the employer's interest in hours per worker. (See Rosen (1986b).) Lewis's model addresses a serious deficiency of the labor supply model: workers on many jobs cannot choose their hours. With Lewis's extension, workers choose their hours by choosing their jobs.

Rosen cites Lewis (1969), and he was deeply aware of Lewis's ideas on the topic. Rosen (1994, p. 142) wrote,

> "Gregg and I had long and heated discussions [in the 1960s] about how wages and working hours were determined when the hours schedules of workers had to be coordinated. The solution required a new and sophisticated equalizing difference model that materially advanced the economics of hours of work. Somehow a manuscript never materialized. Many years later I discovered that he had in fact written an excellent conceptual paper that spelled out many details and published it in Spanish, in a Chilean journal that is virtually unread. The piece probably got wider circulation from duplicates of an English language version I later sent to friends." [5]

This clarifies Rosen's (1974, p. 34) acknowledgment: "The substance of this paper arose from conversations with H. Gregg Lewis several years ago."

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as dentists. That suggests either a slow transition to new equilibrium or barriers to entry; that is, this sixth factor merely sets up their final two factors.

[5] Lewis's working paper (in English) is available at ...

The connection between Lewis's 1969 paper and Rosen's hedonic prices paper warrants a deeper look. Lewis sets out a model of compensating differentials, but his paper would confuse any economist familiar with post–1974 models of compensating wage and price differentials. Lewis's figures display indifference curves, iso-profit curves, and market wage functions in the w–h space, but they do not resemble Rosen's figures; nor do they resemble anything from consumer or producer theory. Lewis plots the relationships with the hourly wage (a price) on the vertical axis; Rosen's graphs have the weekly wage (i.e., earnings) on that axis, and that makes all the difference. The small step from consumption to earnings on the vertical axis means that Rosen retains visually familiar elements of the neoclassical model of choice.

Applications: Value of Human Life and Racial Discrimination Among Teachers

Applications of compensating differentials are many and varied. Examples include product quality and quality-adjusting price indexes, rent gradients in urban economics, capital-asset pricing connecting asset returns to undiversifiable risk, and many applications in labor economics. Rosen followed his hedonic prices paper with two theory-and-evidence papers that estimate compensating wage differentials without trying to uncover the underlying structure.

Thaler and Rosen (1976) are famous for estimating the value of human life from the wage premium on dangerous jobs. By occupation, they match data on wages and worker characteristics from the Survey of Economic Opportunity with fatality data from the Occupation Study of the Society of Actuaries. The slope of the estimated wage-risk function $w'(r)$ is a marginal value: how much workers would accept in lower pay to reduce the risk of death on the job a small amount. A little arithmetic turns that estimate into the answer to this question: "How much pay would 1,000 workers give up annually to reduce the annual risk of death by .001?" Since that risk reduction saves one life (on average), this amount reveals the workers' value of one life. From a linear specification, Thaler and Rosen estimate that workers implicitly value a human life at $1.35 million (in 2019 dollars); the estimated value of life from their log-linear specification is $1.04 million (in 2019 dollars). They also note that the wage differential at any risk r overstates the gain to discrete reductions in risk (and understates the compensating variation associated with added risk) since the compensated demands for job safety slope down.

As a foundation for their empirical analysis, Thaler and Rosen also carefully analyze risk and insurance in the job context. Their analysis adapts Figure 1 to the r–w space of the labor market with wage-risk function $w(r)$. To generate workers' preferences over jobs (r, w), they present models of consumption insurance. Their first model focuses on lost earnings from injuries of workers who have access to actuarially fair insurance. Workers fully insure consumption risk by equalizing the marginal utility of consumption across states. The resulting wage differentials simply reflect lost earnings from cross-job differences in working-time due to injuries.[6] That is, the compensating wage differential is *not* related to risk aversion. Their primary model, however, admits a role for risk aversion by including actuarially unfair insurance. In this model, injuries are fatal, insurance has a load factor, and the living and bequest utility functions are state dependent. The model generates indifference curves in the r–w space that are increasing, convex functions of risk r.

[6] The compensating wage differential vanishes if employers provide the optimal insurance policies.

In addition, more nonlabor income, a bigger load factor for insurance, or stronger aversion to risk steepens the set of indifference curves. So a worker with more nonlabor income, a better price of insurance, or with more aversion to risk chooses a safer job. Discounting dead-state consumption also steepens indifference curves, so a worker with a weak bequest motive chooses a safe job.

For white teachers, what is the compensating wage differential to teach in schools with mostly black students? Race frames the question, but answering the question requires confronting a key aspect of 1960s America: schools were racially stratified. Black schools were bad in many measurable dimensions. So Antos and Rosen (1975) provide evidence to answer a question that is more about the racial gaps in school quality and less about the racism of white teachers: "How much more does a typical white teacher earn to teach in the type of school that a typical black teacher teaches in?" They analyze data from the Equality of Educational Opportunity Survey of 1965 to answer this question.

Teacher quality is important for the empirical task, so Antos and Rosen add one dimension to the underlying model. A teacher chooses a job, a combination of school attributes s (e.g., student quality, student's racial composition, financial resources) and the wage w. A school offers a job (s, w) and also chooses the characteristics of its teachers t, which means the expanded wage function $w(s, t)$ matches teachers and schools.

The racial composition of a school's students is not as important as other features of the school. Antos and Rosen find that "white teachers value student quality very highly and accept significant reductions in pay for the privilege of teaching good students" (p. 145). And controlling for these other attributes of schools shrinks the wage differential associated with racial composition to statistical insignificance.

Antos and Rosen conclude that, for men, moving a white teacher from the average school of white teachers to the average school of black teachers raises annual pay by $850 (2019 dollars). The compensating differential for black men teaching in the average school of white teachers is about $4,000 (2019 dollars). The magnitudes are bit smaller for female teachers.

Spatial Amenities: Wages, Rents, and the Quality of Life

Rosen influenced urban economics immensely. His hedonic prices paper provides the foundation for regressions of housing prices on spatial attributes, such as school quality, the crime rate, pollution, and distance to the city's center. Indeed, he casts his model of product differentiation "as a problem in the economics of spatial equilibrium" (Rosen 1974, p. 34).

But Rosen also left an indelible mark on modern urban economics through the Roback–Rosen model of spatial amenities (Roback 1982; Rosen 1979). Rosen's contribution to the model is a preliminary paper that he published in an obscure volume. He also supervised Jennifer Roback's dissertation at the University of Rochester, and the product of her dissertation research was a pathbreaking *JPE* paper. With over 1,100 citations, Roback's paper is among the most cited papers in the *JPE*, and it continues to generate 75–95 citations per year. Authors cite Rosen's paper much less often, but its 262 citations place it just below Thaler and Rosen (1976) in his top-ten list.

Rosen (1979) frames the issue. How should we rank cities on the basis of quality of

life if a city's housing prices and wages depend on its amenities (and disamenities). Since housing prices and wages are prices that clear the spatial markets, quality-of-life rankings should depend on more fundamental factors: the spatial amenities. And how do we weight the various factors to generate a single ranking? The effects of the amenities on housing prices and wages reveal the marginal prices—how much the markets value or disvalue school quality, crime, pollution, culture, population density, pleasant weather, and so on. That is, coefficient estimates from housing price and wage regressions weight the various locational attributes.

A simple example highlights the role of firms' location choice in identifying the effect of an amenity on wages and uncovers the shortcoming of Rosen's paper. The locational attribute is an amenity like weather; workers prefer nicer weather, but weather does not affect production costs in this example. The classical prediction is that the rental price of housing adjusts to leave workers indifferent across locations. In particular, living in places with nice weather is expensive. Wages do not vary with the weather because land is the fixed factor, and labor is mobile. Roback's model, however, establishes that this cannot be an equilibrium because firms would not locate in those expensive (i.e., nice weather) locations. There is no cost advantage to balance the added cost of land. So wages must carry some of the equilibrating load. These nice locations must have high housing prices *and* low wages.

Rosen models the location choice of consumer-workers, but he omits the location choice of firms. Consequently, his model is under-identified. Optimal choice for each value of the locational amenity s defines an indirect utility function conditional on location s. In familiar fashion, Rosen presents the solution to the problem of locational choice as the tangency of one of these indifference curves to the market wage function (or wage-amenity curve). Here he graphs the real wage (i.e., the ratio w/r) as a function of amenity s.

To separately identify the wage w and housing price r in each city, Rosen would need to model the location choice of firms. He clearly understood this.

> "… the extent to which amenities are reflected in wages or are capitalized in the values of location-specific factors that influence living costs cannot be examined by using the ratio $[w/r]$. Any resolution of this decomposition requires introducing locational decisions of firms and some aspects of intercity trade. … [A]ny equalizing differences in wage rates must feed back into the cost-of-living index because they also alter the price of an important factor in the production of nongraded goods, which in turn affects living costs. Examining the ratio of wages to prices finesses this important problem without resolving it."

The finessing involves squeezing the three dimensions (i.e., w, r, s) of the spatial model into a standard compensating differentials graph. Rosen's solution is to graph the relationship between the ratio w/r and s without separately parsing the effects on wages and housing prices. For instance, if the attribute is a pure amenity (without any effect on the cost of production), Rosen's analysis demonstrates that w/r is lower in nice cities. Hidden is the Roback result that w/r is lower in this case because the housing price is higher; the wage is the same in nasty and nice cities.

Roback closes the model with firm location choice and separately identifies the effects

of amenities on w and r. She also provides a simple way to illustrate a model that belongs in three dimensions. She casts indifference curves and unit-cost curves in the dual space of prices $\{w, r\}$ for discrete values of s. As such, the model looks much different than the standard compensating differentials graph.

Failing to model firm location is a shortcoming of Rosen's paper, but his model also contains a serious error. Rosen includes $w(s)$, the wage (as earnings) as a function of the amenity, in the budget constraint to capture that the amenity can be productive ($w' > 0$) or unproductive ($w' < 0$). The relationship between w and s is, however, something to be determined in the model. From Roback, we know that the productive or unproductive aspect of the amenity belongs on the firm's side of the model. Without the model of firm location choice, Rosen was left inappropriately squeezing the productive aspect into the worker's budget constraint. This error carries over to his derivation of the slope of the indifference relationship between w/r and s; there the slope of the wage-amenity curve slips into the derivation.[7]

Researchers continue to cite Rosen's paper in this obscure volume. The model is incomplete and contains a serious error. I suspect few people have read the paper. I also suspect that researchers decades ago cited Rosen (1979), as well as Roback (1982), to give Rosen some credit for the likely influence he had on Roback's dissertation.

Monopoly and Product Quality

Rosen's model of compensating differentials brings differentiated products, jobs, and workers into the realm of competition as an alternative to Chamberlin's monopolistic competition. This is a prodigious feat. With the exception of the sub-title of the 1974 *JPE* paper "Product Differentiation in Pure Competition," however, Rosen did not directly challenge monopolistic competition. Indeed, he does not reference Chamberlin (1933) or any other work on monopolistic competition.[8]

Do monopolist's downgrade product quality? Does lack of competition encourage planned obsolescence? An important literature in the 1970s studied the effect of monopoly on durability (e.g., Swan 1970; Parks 1974). Since durability is an attribute of the product, the topic gave Rosen a chance to apply his model of compensating price differentials to a noncompetitive market.

Mussa and Rosen (1978) drop competition entirely to study a price-discriminating monopoly that cannot observe the buyers' valuations or prevent resale. Enter product quality. The monopoly offers varieties of its product, and buyers reveal their valuations by sorting among the varieties. Unlike monopolistic competition, where a seller differentiates its product to create power to set price, Mussa and Rosen's monopoply faces competition from its own varieties, which limits its ability to capture consumer surplus. That is, their model features competition in the quality space even though the seller is a monopolist.[9]

[7] The model is correctly specified for the special case in which the amenity is neither productive nor unproductive. If $w' = 0$, then his derivation is correct, although showing that w/r falls with s hides that w does not change at all.

[8] In the final paragraph, Rosen (1974, p. 54) notes that including nonconvexities would produce holes in the attribute space that would naturally incorporate monopolistic competition.

[9] Mussa and Rosen (1978, n. 1) note that their assumption of constant unit cost rules out piling up production

The key result is easy to understand in the context of two varieties of a product. High-valuation people want the high-quality variety, so the monopolist boosts the price they pay. Unfortunately for the monopoly seller, offering a low-quality variety limits the rent capture. The high-valuation buyers are happy to downgrade to the low-quality variety to escape the tyranny. The monopolist's solution is to lower the quality of the low-quality variety to deter escape. That is the key result.

In the continuous product-quality version, the monopoly steepens the price gradient relative to marginal cost to extract more surplus from those willing to pay the most for quality. Buyers tend to downgrade their quality choices since the marginal prices of quality are higher, and the monopoly seller reduces quality at the bottom end. But the seller might also price some low-valuation buyers out of the market. So a price-discriminating monopolist sells lower quality varieties than competitors would in the same market.

One takeaway from Mussa and Rosen's paper is that there is more to product differentiation than creating power to price above marginal cost. Mussa and Rosen's monopolist uses product differentiation to leverage existing power into price discrimination.

Rosen's work on equalizing differences spans many areas of labor economics, urban economics, and product markets with and without competition. Equalizing differences is also the starting point for his approach to inequality.

3. Earnings Inequality

Many of Rosen's other papers reveal his deep interest in inequality. The concentration of rewards in the upper tail of the earnings distribution, as well as skewness of the distribution overall, caught and held his attention. Although differences in skill and effort could go a long way toward explaining inequality, the concentration of lavish rewards on so few remained a troubling mystery. A series of his most influential papers in the 1980s offer solutions.

One modeling strategy connects Rosen's papers on inequality.[10] To skew the distribution of earnings to the right, design a model that generates earnings as an increasing, convex function of something—schooling, ability, skill, or performance. The transformation from the underlying factor to earnings—a change of variables—stretches the right tail of the earnings distribution.

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at isolated point in the quality space, which would lead to monopolistic competition. That is the only mention of monopolistic competition in the paper.

[10]Rosen (1997) is an exception. Risk-averse workers choose occupation lotteries, *seeking* risks to fully insure. State-dependent preferences is the key to this manufactured inequality. An example from Rosen (2002) highlights the connection between locations and occupations. New York City affords great opportunities to spend income; Kankakee, Illinois, not so much. As a result, some risk-averse workers prefer a lottery over compensating differentials. A newly minted lawyer might choose between the sure things of a high-stakes legal practice in New York and a low-key practice in Kankakee. But a new lawyer might prefer a career gamble because New York is the place to have high income. That is, the up-or-out promotion policies in the high-stakes New York firms might provide the gamble that the young lawyers seek. Winners enjoy high incomes that generate lots of value in New York; losers take low-income positions in Kankakee, where income does not deliver as much value.

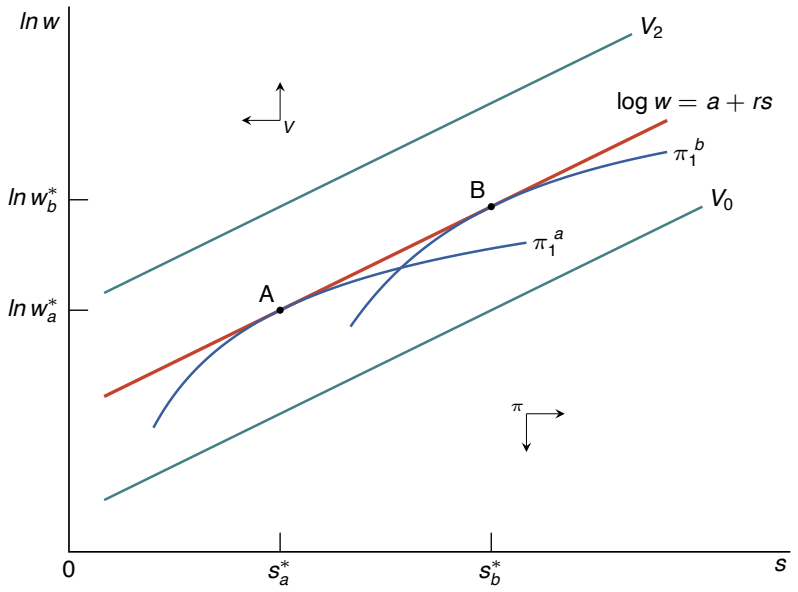

Figure 2. Compensating Wage Differential for Schooling

Schooling

Let's begin with what Willis (1986) calls "Rosen's schooling model." The model recasts the optimal stopping model of schooling implicit in Mincer's model of the earnings distribution as an application of compensating wage differentials. A particular specification connects Smith's (1776 [1994]) ideas through Mincer's (1958) modern statement to Rosen's (1974) compensating differentials. (Rosen (1977) sketches the model.) In this case, the relationship between wages and schooling equalizes wealth across workers and skews the distribution of wages to the right.

In what Rosen would call Smith's model, workers are identical in terms of ability, and everyone can borrow or lend at interest rate r in a perfect financial market. The variable s measures schooling. The separation theorem implies that each worker maximizes wealth V, which is $V = (w/r)e^{-rs}$ if workers live and work forever. To illustrate the model's preference side, solve the wealth expression for $\log w$ as a linear function of schooling.

$$\log w = a + rs \tag{3}$$

where $a = \log rV$. Figure 2 shows a family of three parallel iso-wealth lines with slope r.

The wage-schooling function $w(s)$ defines workers' opportunities. A worker chooses schooling s to maximize wealth at the tangency of an iso-wealth line to the $\log w(s)$ function in the figure. Equilibrium among the identical workers requires indifference across s, so the $\log w(s)$ function, in equilibrium, must coincide with an iso-wealth line. That is, equation (3) is more than an iso-wealth line. *This specification of Rosen's schooling model delivers Mincer's schooling equation as an equilibrium relationship.*

On the employers' side, schooling-specific labor demands pin down employment at each s, which determines the equilibrium distribution of s and also the equilibrium distribution of wages w. Figure 2 displays the profit-maximizing choices for two employers.

The key feature of the equilibrium is that the wage is an increasing, convex function of schooling. In this specification, the wage is an increasing, exponential function of schooling. Therefore, if the distribution of schooling were normal, the wage distribution would be log-normal. If the distribution of s were symmetric, the distribution of w would skew right. And most generally, equalizing differences skews the distribution of w relative to the distribution of s.[11] This schooling model tightly connects Rosen's work on compensating differentials to research on earnings inequality.

The model's implication for inequality is empirically important. For instance, my textbook application of this schooling model matches earnings asymmetry in the 2017 Current Population Survey (CPS) quite well (McLaughlin 2019, p. 379). Applying the estimated schooling coefficient in the log-wage regression (11.7 percent) to the actual distribution of schooling skews the predicted wage distribution to an extent that matches the actual asymmetry of the wage distribution. The ratio of the 90–50 percentile difference to the 50–10 percentile difference is 2.5 in the CPS and 2.85 using predicted wages from the log-wage regression.

Superstars

"The Economics of Superstars" is Rosen's only *obvious* contribution to the economics of inequality. One observation motivates his paper: "In certain kinds of economic activity there is concentration of output among a few individuals, marked skewness in the associated distributions of income and very large rewards at the top" (Rosen 1981, p. 845). Top athletes and entertainers capture large audiences and the lion's share of earnings while the slightly less talented toil away with little reward. Rosen models the phenomenon with a joint (or nonrivalrous) consumption technology that highlights the importance of market size. The equilibrium income of performers is an increasing, convex function of the performer's talent.

Rosen displays what strikes me as modeling genius. The model could be terribly complex. On the buyer's side, the issues include quantity-quality tradeoffs, heterogenous time costs, preference for variety, and so on. On the performer's side, the issues include pricing, lack of competition, market size, dilution of quality as the size of the audience grows, market access (e.g., getting noticed), risk taking (i.e., gambling to make it big), and so on. Sweeping most of these issues away, Rosen designs a competitive model in which joint consumption interacts with market size to concentrate earnings on top performers.

Grasping that technology is the key, he also simplifies the buyers' side dramatically.[12] A separability assumption means that income and intensity of preference for entertainment do not influence the choice of quality. With two other small assumptions, a single price of entertainment connects a simple model of buyers in the market for entertainment with an

[11] The importance of Rosen's schooling model for inequality comes entirely from Mincer (1958), the *JPE* paper from his Columbia University dissertation. It is one of the first models of choice in the context of inequality. Mincer did not solve the optimal stopping problem, but he did deliver the key implications for skewness of earnings distributions; for instance, if schooling is distributed normally, the earnings distribution is log normal. And differences in schooling generate earnings inequality with a long right tail even though wealth is equalized.

[12] The model is grounded in Rosen (1974), and Rosen's (1968) dissertation article also influences the specification of the buyer's problem. The quantity–quality tradeoff with a fixed cost per performance (unrelated to quality) in the superstars model resembles the workers–workweek tradeoff with a fixed cost per worker in his thesis research.

even simpler model of performers producing entertainment.

Buyer's Problem. Utility function $U(x, y)$ characterizes a buyer's preferences over a generic consumption good x and entertainment services y, which is the product of the number of performances n and the quality of each performance z. (This allows ample substitution between quantity and quality.) The budget constraint equates expenditures on goods x and entertainment services y to income. Since the full cost of a performance is $p + s$, where s is a time cost (unrelated to z), the price of a unit of entertainment services is $(p + s)/z$. The final element of opportunities is the price function $p(z)$.

In the z–p space of Figure 1, the buyer chooses quality z at the tangency of an indifference curve to the price function $p(z)$. Here the indifference curves are linear with a common vertical intercept at $-s$. If buyers share a common time cost s (but possibly differ in income and intensity of preference for entertainment), the equilibrium price function must coincide with an indifference line; that is, $p = vz - s$, where the slope coefficient v is the full price of entertainment services. The slope of this line v connects the two sides of the entertainment market.

Seller's Problem. Despite the emphasis on joint consumption, the performer's problem is simple. Assume for the moment that the quality of a performance does not depend on the size of the venue, so we can measure performance quality z and performer quality q in the same units (z). A performer of quality z can sell m tickets at the market price $p = vz - s$. The performer chooses his or her market size m by maximizing profit $\pi = p(z)m - C(m)$ where $p(z)$ is the line $p = vz - s$. The solution equates price to marginal cost given z. Since $p' \equiv v > 0$, more-talented performers service larger markets.

Equilibrium. The equilibrium specifies a value of the full price of entertainment services v^* that equates the quantities demanded and supplied of entertainment services. Since entertainment demand slopes down and supply slopes up, existence of equilibrium is straightforward. Three special cases illuminate the model's properties.

If marginal cost increases in market size, joint consumption is not a feature of the model, and the model loses its public-good flavor. Nevertheless, the market rewards talent at an increasing rate. Talented performers sell tickets at higher prices and sell more tickets; the product of the two generates convexity of the return to talent. In a simple numerical example with a quadratic cost function, Rosen shows that price and quantity increase linearly in quality z, so the income of performers increases in the square of quality. A performer who is twice as talented as another earns four times as much.

Switching to joint consumption would surely concentrate more income on the top performers. Not necessarily. In fact, as Rosen demonstrates, the paper's takeaway result does not hold in the pure joint-consumption case. With marginal cost of market size zero (i.e., joint consumption), the most-talented performer supplies the whole market. The superstar services the whole entertainment market *but earns zero rents* if there are no gaps in the distribution of performer quality. Potential entry drives the price v^* down to the value that leaves only one performer. If, however, the superstar is a discrete distance above the rest of the quality distribution, then she earns rents. Even if the rent per ticket is small, the superstar earns enormous rents by serving the whole market.

Rosen also combines joint consumption with a crowding condition (e.g., that large

venues dilute the quality of the performance). Crowding weakens joint consumption's push to concentrate earnings at the top, but it cures the fishy property of a rentless superstar. If quality does not deteriorate too quickly with market size (and decays less for talented performers), then price does not fall much as quantity rises, and income of performers increases in talent at an increasing rate. In another numerical example, Rosen shows that if market size m adjusts entertainment quality z down from performer quality q by a term in the square root of m/q, then m grows with the cube of talent, and income grows by the power of four. That is, a seller who is twice as talented as another earns sixteen times as much.

How does demand for entertainment influence the concentration of earnings at the top? An increase in the number of consumers or in the intensity of their demands for y increases the equilibrium price v^* since entertainment supply is an increasing function of its price. Each performer faces a higher price for his talent p, so every performer chooses to service a bigger market (and less-talented performers enter the market). Rents increase, and the largest increases go to the most-talented performers. Thus increasing the size of the market amplifies skewness of the rewards.

In this paper, Rosen essentially declares that concentration of output and earnings on a small number of top performers is *not* from lack of competition, exploitation of struggling artists, failure to be noticed, or other problems. If a single performance (or recording) can be sold to thousands or even millions of consumers, a *competitive* market richly rewards the top talent for being just a little better than the not-quite-top performers because the technology concentrates the audience and earnings on the top performers. In these markets, richly rewarding tiny differences in talent is not arbitrary; it is the competitive outcome.

Hierarchies and Sorting

Top managers, like top performers, are richly rewarded. Although entertainment and management surely differ in many ways, Rosen's (1982) model of managing in corporate hierarchies highlights the similarities between superstars in entertainment and management. A performer can sell one performance to a vast audience (i.e., joint consumption); a talented manager can leverage one good idea to improve everyone's output (i.e., managerial economies). As crowding (diluting quality) limits a top performer's market, a time constraint limits a manager's ability to supervise big teams, diluting the time she can spend helping each team member. And these similarities carry over to the principal results. Managerial compensation increases with ability at an increasing rate, which skews the distribution of earnings, concentrating rewards at the top of ability distribution.

Model. The equilibrium assigns heterogenous workers to production or management jobs and determines the quantity of quality-adjusted labor that each manager supervises. If supervised by a talent–r manager, worker i with production quality q_i produces $x_i = g(r)f(rt_i, qi)$, where t_i is the time the manager spends supervising worker i. Given r, the worker's output is an increasing function of the effective time with the manager rt_i and the worker's quality. The increasing function $g(r)$ models managerial economies as a Hicks neutral term. The time-augmenting scaling (via r) of supervision time captures that better managers can more effectively help each worker. This time-augmenting feature attenuates the effect of the time constraint in limiting the size of a manager's team.

Properties. First, each manager allocates time across the team by equalizing marginal

products of supervision f_1. Second, if f is constant returns to scale, then supervisory time t_i is proportional to quality q_i. Third, as a consequence of optimal time allocation and constant returns, the output of the team is $X = g(r)\theta(\frac{rT}{Q})Q$, where T is the manager's total time, Q is total quality of the team, and θ is an increasing, concave function. So with r fixed, there are diseconomies in Q as the manager's supervision time is spread more thinly over more production labor. Fourth, choosing team size to maximize profit pins down the manager's optimal span of control Q/r, which is an increasing function of manager talent r. Fifth, more-talented managers manage larger teams Q and generate more output X. Sixth, managerial compensation is an increasing, convex function of managerial talent. The scale economies of superior management skew the distribution of rewards relative to the distribution of talent.

Selection. A worker of ability a chooses between being a production worker, earning wage w for each unit of production quality q, or a manager earning the compensation associated with her managerial talent r. (Two lines generate q and r from the single latent factor a.) Job choice involves comparing the linear (with slope w) earnings function on production jobs with the increasing, convex rewards for managers. The two functions cross, and higher ability people choose to be managers. Equating the quantities demanded and supplied of production labor determines the total value of Q, which also determines the marginal worker. And the marginal worker's indifference between being a production worker and a manager sets the level of managerial compensation. Most import, self-selection adds convexity to the reward structure. Even without the managerial economies, self-selection convexifies earnings overall: earnings grow with ability at a constant rate on production jobs and a higher rate on managerial jobs.

Rosen sketches the effects of self-selection on earnings inequality in his *Economica* paper on "Substitution and the Division of Labor" (Rosen 1978, section 2). There he explores equilibrium in the context of a generalized Roy (1951) model, for instance, deriving upward-sloping product supply functions from a fixed distribution of worker talents and fixed-proportions production functions. In this setting, he analyzes the implications of selection for skewness, noting that positive selection to each task (or occupation) positively skews the income distribution. Rosen is silent on skewness in the case of a mix of positive and negative selection (i.e., the hierarchical case), although self-selection in the log-normal Roy model skews the overall distribution of earnings even in the hierarchical case (Heckman and Honoré 1990).[13] In an application of the Roy model, Willis and Rosen (1979) famously find that workers are not ordered by skill: college graduates would be below-average workers on high school jobs. This pattern of positive selection into each sector positively skews the distribution of earnings, but Willis and Rosen do not explore this.

Tournaments

Lazear and Rosen (1981) motivate their classic paper on performance incentives in tournaments with the observation, "… the large salaries of executives may provide incentives for all individuals in the firm who, with hard labor, may win one of the coveted top posi-

[13] Of course, Rosen's paper predates Heckman and Honoré's result by more than a decade, but Neal and Rosen's (2000) survey of earnings inequality models also omits the result. The survey highlights skewness implications of various models, but the presentation of the Roy model curiously omits the effects of self-selection in skewing the overall distribution of earnings.

tions" (p. 841). Although they focus on the advantages and disadvantages of piece rates, bonuses, and tournaments (dealing with adverse selection, handicaps, common production shocks, and cardinal versus ordinal costs of measuring performance, etc.), the distribution of earnings is an important piece of the paper's puzzle.

The paper features Rosen's concern for the concentration of rewards at the top, but here the superstar earns more that he or she is worth. As Lazear and Rosen argue, it is difficult to reconcile the tripling of a VP's salary on the day he or she is promoted to CEO with marginal productivity theory. In the tournament model, the firm rewards that VP for winning the race to become CEO, and the sizable jump in pay is the prize that encourages everyone on lower rungs of the corporate job ladder to work hard. The prize motivates performance on the way to the CEO's office.

In the subsection "Income Distributions," Lazear and Rosen find that a risk-averse worker's preference for piece rate or tournament compensation depends on wealth. If workers sort to their preferred form of compensation, the earnings distribution mixes the distributions of low-wealth piece-rate workers and of high-wealth tournament workers. The overall distribution of earnings skews to the right.

Since Lazear and Rosen model a tournament with a single prize, they cannot explore how the size of the prize varies within a corporate job ladder. Do prizes increase at an increasing rate, skewing earnings to the top of the distribution? Rosen (1986a) answers this question in the context of multiple rounds of a single-elimination tournament: winners work their way toward the top of the corporate hierarchy. Rosen solves for the prize structure that equalizes effort throughout. His key result is that the prize in the last round takes a discrete jump from the pattern across lower rounds. With risk-averse workers, the prize Δw grows at an increasing rate from round to round and jumps up in the final round. (If workers are risk neutral, the prize grows linearly with rank before jumping at the top rank.)

The feature that drives the model is the finite horizon. In each round, the payoff to winning is the prize *plus* the option value associated with continued play. The option value shrinks from round to round as workers get closer to the top, and the option value vanishes in the final round. To equalize effort across rounds, the prize must grow to offset the decline in the option value, and the prize must be unusually large in the last round since there is no option value. So compensation is an increasing, convex function of rank with a particularly large reward at the top rank.[14]

Lazear and Rosen (1981) and Rosen (1986a) contribute to our understanding of compensation strategies, and that is the source of their great influence. But the two papers also advance the economics of earnings inequality, breaking competitive compensation free of the restraints of marginal productivity theory.

4. Surveys and Other Papers

Rosen's surveys display his skill as a synthesizer of research.

His contribution to the first volume of the *Handbook of Labor Economics* is a sur-

[14]This result is for equally talented contestants. Rosen derives similar results in heterogeneous-contestant specifications with known talents and unknown talents.

vey of equalizing differences in labor markets (Rosen 1986b). Of course, he translates the compensating price differentials model to the labor market, but he also presents a binary version of the model. Each job is either clean or dirty, and varying the relative wage $\frac{w_d}{w_c}$ sweeps out the distributions of tastes and clean-up technologies, generating a downward-sloping demand for workers on dirty jobs and an upward-sloping supply of workers to those jobs. Rosen also surveys applications of equalizing differences to working conditions, human capital, uncertain prospects in career choice, working hours (circling back to his heated discussions with Lewis), and unemployment risk.

Rosen's (1977) survey of human capital sharply distinguishes efficiency-units and equalizing differences approaches. In the context of the schooling model with efficiency units, Rosen argues that the only source of earnings inequality is heterogeneity of ability and interest rates; schooling contributes nothing to understanding inequality in this case. With equalizing differences, schooling-specific demands for labor give rise to the schooling distribution, which generates an earnings distribution even without differences in ability and interest rates. Importantly, the relationship between log earnings and schooling has no structural interpretation if schooling generates efficiency units of human capital. With equalizing differences, however, the relationship (equation 3) is structural; it identifies the objective function. Rosen's concern for the identification of a causal relationship between earnings and education in the context of heterogeneity predates Card's (1999) important survey of the same topic by over two decades.

On the heals of a burst of theoretical research on implicit contracts, Rosen surveyed state-contingent employment without and with private information in an influential *Journal of Economic Literature* piece (Rosen 1985). In the context of full information, he shows how employers, insuring workers against wage shocks, smooth consumption but amplify the volatility of employment fluctuations. This is fully efficient. Turning to private information, where the key issues are underemployment and excessive employment fluctuations, Rosen synthesizes the disparate results in the literature. Passing each paper through a general statement of the problem, he shows why different papers produce different results. In particular, Rosen demonstrates that the papers with underemployment and excessive employment fluctuations have either workers insuring risk-averse firms or leisure as an inferior good.

Rosen's (1992a) survey of executive compensation joins theory to evidence. He organizes the synthesis into three parts. First, echoing the theme of Rosen (1982), he sketches a new model of the *assignment* of managers to positions in corporate hierarchies on the basis of talent. The model generates a linear relationship between earnings and managerial talent within each level, but overall earnings is an increasing, piecewise linear, and convex function of talent. Rosen links this implication to estimates of the effect of firm size on executive compensation. Second, in the context of *incentives*, Rosen connects the empirical literature on the sensitivity of executive compensation to firm performance to agency models of incentives and risk sharing. He argues against economists' aversion to using accounting measures of firm performance. He also surveys the evidence on relative-performance compensation. Third, the section on *identifying new talent* analyzes career incentives and applies his models of tournaments.

Neal and Rosen (2000) surveyed models of earnings inequality for the *Handbook of Income Inequality*. They explore several strategies to explain the evidence that earnings

distributions skew to the right with the top percentiles of earners accounting for a disproportionate share of total earnings, and earnings dispersion growing with work experience. The classification of models reflects Rosen's contributions to the topic: scale of operations (e.g., Rosen 1981), selection models (e.g., Rosen 1978), human capital models (e.g., Mincer (1958)), and agency models (Lazear and Rosen 1981; Rosen 1986a). Neal and Rosen evaluate a wide variety of economic models in terms of their importance for earnings inequality, and their evaluations reflect Rosen's approach to inequality.

"Markets and Diversity" presents Rosen's (2002) vision of markets as harbors of diversity. In this essay, which was his presidential address to the American Economics Association, Rosen frames the issue with a question: "How do decentralized markets accommodate the diversity of choices, tastes, and productivities that are so important in economic affairs?" (Rosen 2002, p. 1). He organizes his answer into three parts: (1) value in the presence of diversity, which is about the implicit prices of the attributes of goods, services, jobs, and workers; (2) sorting and stratification of diverse buyers to diverse sellers (and connecting to his papers on specialization and division of labor (e.g., Rosen 1978, 1983)); and (3) socially valuable economic inequality arising from specialization and sorting. One theme is that inequality is, in large part, manufactured by the actions of identical people.

Occupations: Lawyers, Teachers, and Engineers

Why do workers in some occupations (or industries) earn more than workers in others? Rosen pursued this question early in his career (Rosen 1969a, 1970), and he returned to it to study the markets for lawyers, teachers, and engineers. Do our models explain employment and wage patterns in a particular occupation?

Are lawyers paid more than they are worth? Rosen (1992b) shows that the pay of lawyers is in line with the return to schooling, tuition and foregone earnings during three years of law school, the long workweek of lawyers, and self selection into law school and the legal profession. Flyer and Rosen (1997) analyze how the size of the baby-boom cohorts, squeezing their way through schools, affected employment and wages of teachers over decades. Ryoo and Rosen (2004) estimate the dynamics of occupational choice in the context of engineers, a profession with sizable and predictable shocks in employment demand. The flow of graduates with engineering degrees tracks fluctuations in the expected present value of wages. In addition, the time to train a new engineer generates overshooting even with rational expectations.

Dynamics: Housing, Cattle, and Potatoes

Rosen's strong interest in dynamic models shows in his early work on dynamic factor demand (e.g., Nadiri and Rosen 1969) and human capital (e.g., Rosen 1976) as well as his final work with Ryoo on engineers. In the late 1980s and 1990s, Rosen also studied the dynamics of housing, cattle, and potato markets.

Topel and Rosen (1988) apply an extension of the investment supply model to the housing market. Their extension allows construction supply to be more elastic in the long run than the short run. In the standard investment supply model, the demand for housing services depends on the rental price of housing, and new construction depends on the price of housing. Expectations, static or rational, connect the housing price in construction supply

to current and future rental prices in housing demand. An internal adjustment cost allows investment (i.e., new construction) to be more elastic in the long run and implies that expected future prices of housing affect investment supply. Topel and Rosen precisely estimate a sizable adjustment-cost parameter, which delivers a long-run elasticity of construction supply that is about three times the short-run elasticity.

It takes four years to train an engineer, and it takes two years to raise cattle that are ready for market or breeding. Rosen, Murphy, and Scheinkman (1994) show that this time to build produces long cycles that match the cycles in the stock of beef cattle. A permanent increase in the demand for beef increases the stock of cattle in the long run, which *reduces* beef production in the short run as ranchers shift cattle to breeding. Combining this fascinating dynamic with the two years from breeding to slaughter produces long cycles in the stock of cattle without any cycle in beef consumption.

A rancher decides how many heads to bread and how many heads to market, and a potato farmer splits the harvest into seed and market potatoes. Rosen (1999) applies cattle dynamics to the Irish potato famine that began in 1845. The potato blight reduced the productivity of seed potatoes, raising the marginal cost of potatoes. The blight also lifted demand for seed potatoes: for any price and quantity demanded of market potatoes, post-blight production required more seed potatoes. Rosen contends that Irish farmers acted as if the first season of blight was just a bad harvest (i.e., temporary), responding rationally (given that belief) by holding potatoes as seed that (with the benefit of hindsight) should have been consumed. After the second tragic season, the Irish potato market resembled the dynamics stemming from a permanent, negative shock to the productivity of seed potatoes.

5. Conclusions

The *JPE* honored Sherwin Rosen with a special issue in February 2004. Most of the contributed papers are in labor economics. In 2003, the Society of Labor Economists created the Sherwin Rosen Prize for Outstanding Contributions to Labor Economics to honor the most productive young labor economists. That is fitting because Rosen was surely one of the great labor economists of the first four decades of modern labor economics.

Rosen's most influential paper, however, was not in labor economics. His classic on hedonic pricing applies equalizing differences to product markets. Although the paper fails in its ancillary purpose of structural identification, Rosen creates *the* model of compensating price differentials. That model ranks with Becker's (1965) household production model and Lancaster's (1966) linear characteristics model as a striking extension of the theories of consumer and producer choice.

Rosen was also an inequality economist. Including a labor economist's perspective on models of earnings inequality in the *Handbook of Income Inequality* makes sense. But Rosen's contribution (with Derek Neal) is more than a survey of the labor economics of earnings inequality. It is a tour of Rosen's approach to labor markets with plenty of links to other important contributions. His papers fit hand in glove with earnings inequality.

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