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**MINES AND MIGRANTS
IN SOUTH AFRICA**

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Mines and Migrants in South Africa

By Robert E. B. Lucas*

Between 1971 and 1978 wages of more than half a million nonwhite laborers in the South African mines tripled in real terms. In the same period, the nonwhites employed in the mines switched from being 62 percent foreign to 62 percent domestic.¹ These changes followed a period -- from 1911 to 1971 -- during which real wages of black gold miners did not rise, and terminated almost a century of reliance on foreign labor "reserves" for the majority of such labor.²

These dramatic events are examined here in the context of an econometric model of the demand for labor by the South African mining sector from 1946 to 1980. This affords an unusual opportunity to study the demand side of a market for internal and international migrants, in a society where racial discrimination is formalized in the apartheid system, where powerful mining houses wield potential monopsony power, and political factors in the region are major determinants of economic behavior.

To comprehend the derived demand for workers in this sector, it is essential to outline at least certain aspects of the industry's organization and that of the market for labor. This is undertaken in section I, section II develops a stylized model, which is then estimated, from data described in III, for the gold, diamond, coal and other minerals sectors separately in section IV.

I. Organization of the Mine Labor Market

Ninety percent of the 700,000 workers employed in the South African mines in 1980 were nonwhite. Most are employed in mines affiliated with the Chamber of Mines, one of whose chief functions is to organize hiring and wage policy for the sector. For example, the Chamber -- an organization of employers without government or labor representation -- for many years imposed on members a "maximum permissible average" wage they might offer nonwhites and today effectively imposes a minimum also. Almost all gold, diamond and coal production -- employing 431, 19 and 80 thousand nonwhites respectively in 1980 -- is by mines affiliated with the Chamber. Some extraction of other minerals (employing 109 thousand nonwhites) is also by affiliated mines and several of

the nonaffiliated mines are owned by the half dozen mining houses which dominate the Chamber. Nonwhite labor is recruited for members of the Chamber by licensed agencies, much the largest of which is now called The Employment Bureau of Africa (TEBA). Although the diamond sector is affiliated with the Chamber, it is not a member for labor purposes and this has had profound effects for wages in this sector to be explored later. Moreover, only one mine in the other minerals sector employs TEBA to recruit its labor. Naturally, the centralization of hiring in recruiting agencies subject to the decrees on wages set by consent in the Chamber places the industry in a potentially monopsonistic position if faced with an upward sloping supply of labor.

Foreign workers are hired on contracts varying in length from six months to two years, according to country of origin. At the end of their contract, workers are required to return to their own country and none is permitted to bring his family with him. Not surprisingly this system -- designed in part to allow men to return for ploughing and consequently not put pressure on wages by rendering the family entirely dependent on mine earnings, partly to avoid more permanent settlement of foreign blacks albeit without their families -- generated very high turnover rates of labor in the sense of not returning after a compulsory home visit. Until the mid-1970's black workers could not elect to quit a contract (illegal quitters being termed deserters), not until a boycott by American unions of South African coal imports, on the grounds they were produced by indentured labor, prompted the abolition of the "master and servants" acts. Since then, the fixed period contracts have, of course, dwindled in importance though nominally they still exist.

In 1973, Malawi and Mozambique were the two largest suppliers of foreign labor, providing 39 and 27 percent of foreign labor respectively. In 1974, President Hastings Banda cut off further recruiting of mine workers from Malawi -- ostensibly because of the crash of a plane full of recruits. Since miners from Malawi were recruited on two year contracts, the effect took two years to work through, but the number of Malawians employed in the mines fell from 140,000 in 1974 to 2,000 in 1977. At almost the same instant, the FRELIMO government finally succeeded in ousting the Portuguese. Whether the subsequent sharp decline in Mozambican recruits reflected the demands of the South Africans or exigencies of the new regime remains a matter of debate. [See First (1977)]. But overall there existed, after 1974, an excess supply of foreign workers as mine wages rapidly doubled and tripled. In Botswana and

Lesotho, many experienced men are turned away. Very few foreign novices are now taken and even current, experienced workers are generally only rehired after their compulsory annual home return if issued with a Valid Reengagement Certificate (VRC). VRCs are issued to about 70 percent of workers, subject to "good" performance, but obviously the rate of issuance may be varied to control numbers. Thus, when Malawi again lifted the ban on recruiting in 1978, an excess supply of Malawian recruits emerged for a now limited number of openings.

South African black workers are broadly bifurcated into those with and without section 10 rights.³ Those without must return to their designated homeland each year and must leave their family behind while working in a white prescribed area. Section 10 workers are on average better trained, more urbanized and better educated in a society where educational policy towards blacks has handicapped industry through lack of skilled labor. In 1970, average earnings of nonwhites in manufacturing were exactly three times those in gold mining. Combined with atrocious working conditions, the social stigma attached to mining in South Africa, and the separation from family and potential loss of section 10 rights ensuant upon relocation, this meant mining attracted virtually no section 10 workers who naturally preferred manufacturing. Employers in manufacturing also preferred section 10 workers because of their skills and because they were required to hire labor within their own Labour District rather than importing domestic or foreign migrant workers.

The labor force without section 10 rights faces four alternatives: to gamble on being allocated a manufacturing job through the Labour Bureaux; to squat as an agricultural worker at a rate of pay which for regular employees even in 1969 was well below the mining wage; to practice subsistence farming on the exceedingly poor lands allotted to nonwhites; or to be recruited by TEBA for mining. As mine wages rose in the 1970's, the last alternative became relatively more attractive although wages in agriculture and manufacturing, and employment in the latter also rose somewhat. For example, the Zulus, whom recruiters believed would never work below ground, now do so. Indeed, by 1979 even South African labor was in excess supply to mining. In large part, this is attributable to forced relocation of massive numbers of squatters from white farms to homelands in the late 1970's, nominally for security reasons, expanding the pool available to mining and rapidly diminishing the marginal product in subsistence farming.

Unlike nonwhites, white mine workers have been unionized throughout this period, and average earnings of whites in gold mining in 1970 were over 20 times greater than those of nonwhites. Under the apartheid system a rigid color bar is imposed on access to certain occupations, a regime vehemently defended by the (white) Mine Workers' Union. Even so there has been some realignment of job tasks within occupations, a part of which was formalized in an agreement between the mines and the Mine Workers in 1973, but which has progressed informally since.

The 1970's also witnessed unprecedented increases in mineral prices. After 1971 the producer price of gold began to rise relative to the South African cost of living index. By 1974, the real price was 2.9 times the 1971 level and by 1980 the increase was 6.7 fold, though the path was not monotonic in the interim. Over the same period real diamond prices increased 2.7 times, though 1980 prices remained below the 1946-51 average in real terms, 1971 having been the low point in a steady decline. Coal prices are regulated in three categories: the price paid by the electricity authority is negotiated bilaterally, sales to the remaining domestic market are at administered prices, and exports fetch a much higher price but are effectively limited by port facilities. The average producer price of coal rose only gradually in real terms from 1946 to 1973, then increased 2.4 fold by 1979 as the administered price was raised. Prices of other minerals in 1980 were on average about equal to those in 1969 in real terms, though a very slight rise occurred in between, and remained well below the real prices prevailing in the Korean War era.

Finally, before turning to the model, some of these elements may be pulled together to emphasize the sequence of events. Apart from diamonds, the rest of the mining sector behaved fairly uniformly from 1946 to 1971. After 1971, the Chamber decided to begin raising wages of nonwhites, linking this with stabilization of the labor force in the sense of reduced turnover.⁴ The motivations for raising wages initially were at least three-fold: a concern for the publicity in both the domestic and world press being given to the very low wages then paid; an efficiency wage argument, enhancing productivity through nutrition and health, the prevailing rates often being described as starvation wages; and the hope of reducing turnover and attracting more skilled workers. In an inherently dangerous industry and one where security from theft (especially in diamonds) is vital, a stabilized labor force is at a premium, though possibly at the cost of increasing organization and

politicization. The initiative to raise wages apparently stemmed from the Anglo American corporation and particularly from new directors appointed about 1971, but was rendered possible only in an environment of rising gold prices after 1971 and of coal subsequently.⁵ In the diamond mines, these changes began much earlier -- from 1964 onwards -- despite declining real diamond prices at the time. In that instance, the personal role played by Harry Oppenheimer cannot be discounted nor the role of security risks. From that time onwards, wage policy of the diamond sector was independent of that of the Chamber, the diamond mines not being affiliated for labor purposes, and wages were well above those in the rest of the industry.

After 1974 an era of excess supply of foreign labor follows. Though not everyone in the industry agrees, this probably resulted from a desire to reduce dependence on foreign labor.⁶ Such a desire would have been induced by the uncertainties stimulated by the Malawi cut off in 1974, the FRELIMO takeover in 1975, and the mine compound disturbances of 1975 (reputedly leaving some 200 dead) prompted by a compulsory deferred pay scheme introduced by Lesotho. To attract sufficient South African workers wages continued to rise.

After 1979 the mines were at full complement of labor and South African workers in excess supply to the industry as chronic underemployment in the homelands was well established under compulsory relocation. From 1978 through 1980, real wages of nonwhites remained almost constant. The industry is now split. Some mining houses wish to raise wages further; others want to lower them again, with the realization the latter would mean more employment. The South African government has encouraged the wage increases in the industry. Though concerned with the economic viability of the homeland situation they have created, their enthusiasm for expanded employment of blacks in mining is not clear, for with the exception of Bophuthatswana the mines are too far from the homelands. The government would prefer to see employment created along the peripheries of the homelands, for the primary concern is protection of the exclusive white environs.

II. A Stylized Model.

A. General form.

The story may be broken into two major periods -- before and after 1974. In the earlier era, potential monopsony and job discrimination are major features. In more recent times, excess supply of foreign labor and a possible

preference for reduced dependence on foreign labor are added.

a. Prior to 1974.

Before 1974 it is assumed no excess supply of nonwhite labor to the mines existed either within South Africa or from abroad. To allow for the possibility the combined supply ($f + s$, where f is foreign labor supply, s is South African supply) is less than infinitely elastic with respect to the wage for nonwhites (w), the supply function on which the sector operates is written:

$$1. \quad f + s = F(w)$$

Job segregation under apartheid, substantially different access to education and training for nonwhites, enforced migrancy resulting in high turnover, and low wages generating poor health and nutrition all act to keep productivity of nonwhites below that of whites. Recognizing this distinction between nonwhite (b) and white (ℓ) labor employed, output (q) is expressed as some function:

$$2. \quad q = q(b, \ell, k)$$

where k is capital stock.

With the exception of diamonds it is assumed that producers are price takers in the commodity market. The flow of gold is small compared to the world stock and as a first approximation it is not unreasonable to imagine prices determined by international portfolio behavior rather than through flow supply and demand. The producer price of coal has also been regulated throughout the period under consideration as outlined in section I.

In acting as a potential monopsonist but not monopolist, it is assumed the non-diamond sectors, at least, have been willing to hire nonwhite labor up to the point where marginal cost equals value of marginal product subject to the production function (2). In other words, discrimination against nonwhites is confined to job discrimination as reflected in the production function rather than to additional wage discrimination.⁷ In fact, this is probably a very plausible assumption, for if anything the concern of the mining houses has been to reduce even job discrimination as reflected in their 1973 agreement with the white Mine Workers' Union noted earlier and in the revisions in job tasks. Nonetheless, some results on tests for an extended model incorporating wage discrimination are cited in section IV.

The wages (v) of white workers are determined through bargains struck with the Mine Workers' Union and hence are taken as exogenous to this model. The first order conditions with respect to both types of labor therefore yield:

$$3. \quad p \cdot q_b = w'(f + s) \cdot b + w$$

$$4. \quad p \cdot q_{\ell} = v$$

where p = price of output,

q_j = marginal product of factor j ,

$w'(f + s)$ = partial derivative of w with respect to $f + s$.

The model for this first stage is then closed by assuming:

$$5. \quad f + s = b.$$

b. After 1974

In the second stage, three major changes in the model are necessary: a preference not to rely on foreign labor is allowed for, as a result foreign labor is in excess supply, but this is accompanied by a more stable labor force which may be more productive. To characterize this phase, a supply function of domestic labor to the mining sector must be distinguished.

$$6. \quad s = s(w)$$

Moreover, the production function requires modification for reasons to be discussed in (B), but for now we may simply write this as:

$$2'. \quad q = Q(b, \ell, k)$$

First order conditions must now be distinguished for domestic and foreign labor separately, thus for domestic, foreign and white labor one obtains:

$$3'.i. \quad p \cdot Q_s = w'(s) \cdot b + w$$

$$ii. \quad p \cdot Q_f = w + \psi$$

$$4'. \quad p \cdot Q_{\ell} = v$$

where Q_j = marginal product of factor j ,

$w'(s)$ = partial derivative of w with respect to s ,

ψ = a coefficient of preference not to rely on foreign labor.⁸

It is intriguing to note that this preference against foreign labor has not taken the form of wage discrimination. Foreign and domestic labor continue to be paid equal wages. A potential reason might be tension in the compounds between miners living and working together but rewarded differentially. Yet this friction might be avoided by means of a foreign remittance or recruitment tax. For such taxes there are precedents, though revenue, collected by the mines or recruiting agencies, has gone to the sending countries. I believe the true reason for maintaining equal wages has stemmed from the initial cause of pay increases - sensitivity to accusations of paying exploitative wages.

B. Specific form.

To estimate this system, specific forms of the production functions and nonwhite labor supply functions must be imposed. The overall labor supply

function, (1), is assumed to have constant wage elasticity η and is specified as:

$$7. \quad \ln b = \gamma_0 + \eta \cdot \ln w + \Gamma \cdot X + \gamma_1 \cdot \ln b_{-1}$$

where b_{-1} is b lagged by one year, a term included to reflect the effects of the two year contracts prevalent in some of the major supplying countries, remembering that such contracts were binding prior to repeal of the masters and servants acts. X is a vector of principal components of exogenous elements, both abroad and within South Africa, likely to have shifted the supply function⁹.

As noted in section I, jobs in the South African manufacturing sector have paid nonwhites much better wages than mining. But availability of the former has been limited, particularly for those without section 10 rights who are the really potential mine workers. The supply of South African nonwhite labor to the mining sector is therefore made a function of the expected wage in manufacturing (m). In addition, supply is likely to rise with the size of the nonwhite male labor force (n). Given this, a constant wage elasticity (σ) specification of (6) is again adopted:

$$8. \quad \ln s = \sigma_0 + \sigma \cdot \ln w + \sigma_1 \cdot m + \sigma_2 \cdot n + \sigma_3 \cdot \ln s_{-1}$$

Capital inputs are in fact divided into two types -- fixed capital (k) and equipment (e). In selecting a form of the production function for derived demand analysis it is important to allow for substitution between factors. Four factors of production ($b, \ell, k, \text{ and } e$) and their interactions necessarily imply a lengthy formulation, and within these general requirements two specifications are explored -- a translog and a quadratic. (For a discussion of the properties of each see Fuss, McFadden and Mundlak (1978).) The quadratic form is:

$$9. \quad q = \alpha + \beta \cdot b + \lambda \cdot \ell + \kappa \cdot k + \epsilon \cdot e \\ + \beta\lambda \cdot b \cdot \ell + \beta\kappa \cdot b \cdot k + \beta\epsilon \cdot b \cdot e \\ + \lambda\kappa \cdot \ell \cdot k + \lambda\epsilon \cdot \ell \cdot e + \kappa\epsilon \cdot k \cdot e \\ + 1/2(\beta\beta \cdot b^2 + \lambda\lambda \cdot \ell^2 + \kappa\kappa \cdot k^2 + \epsilon\epsilon \cdot e^2) \\ + \beta\tau \cdot s \cdot T + \tau \cdot T$$

The last two terms require some additional explanation. T is a dummy variable turned on after 1974. Thus $\beta\tau$ reflects any change in productivity of nonwhite labor in the later period, as the labor force is localized with the intent of establishing a more stable, experienced work force. But this period also experienced very sharp rises in mineral prices, and some mines began to rework previously abandoned deposits and several open cast coal mines commenced

operation, each with inherently different productivity -- hence the term τT . The translog version of (10) is of course identical except q, b, λ, k, e and s are each replaced by their natural logarithms.

Solving the first order conditions subject to these specific forms provides for the quadratic case:

$$10. \quad b = \frac{-\beta}{\beta\beta} + \frac{(1+\eta)}{\eta \cdot \beta\beta} \cdot \frac{w}{p} \cdot (1-T) + \frac{1}{\beta\beta} \cdot \frac{w}{p} \cdot T + \phi \cdot T - \frac{\beta\lambda}{\beta\beta} \cdot \lambda - \frac{\beta\kappa}{\beta\beta} \cdot k - \frac{\beta\epsilon}{\beta\beta} \cdot e$$

$$\lambda = \frac{-\lambda}{\lambda\lambda} + \frac{1}{\lambda\lambda} \cdot \frac{v}{p} - \frac{\beta\lambda}{\lambda\lambda} \cdot b - \frac{\lambda\kappa}{\lambda\lambda} \cdot k - \frac{\lambda\epsilon}{\lambda\lambda} \cdot e$$

ϕ expresses the preference not to rely on foreign labor in units of labor and is assumed constant, so that in the quadratic case $\Psi = p \cdot \beta\beta \cdot \phi$. A negative value of ϕ indicates a preference against foreign labor, a zero value implies no such preference. Comparing (3'.i) and (3'.ii) it is readily seen that $\Psi = w' \cdot b + p \cdot (Q_f - Q_s)$, so that if no monopsony power were exercised vis-a-vis South African labor in this period and if foreign and domestic workers were perfect substitutes, ϕ would be zero.

In the context of the translog production functions, all terms in $b, \lambda, k,$ and e are replaced by their natural logarithms, and w and v are multiplied by their respective own factor amount over output.

The system of equations (10) assumes instantaneous adjustment. A simple, flexible accelerator may however be appended by adding a lagged dependent variable term to each equation. The well-known interpretation is that all terms in (10) are thereby multiplied by one minus the flexible accelerator coefficient.¹⁰

Finally, as mentioned earlier, the model is to be estimated for each of the gold, diamond, coal and other minerals subsectors separately. For gold and coal, (10) is appropriate, but for the other two some modification is necessary. The extraction of other minerals is almost entirely by mines which do not recruit through TEBA and commonly not members of the Chamber. It is unlikely these mines have restrained their hiring to help the monopsony position of the industry as a whole, so they are assumed to have behaved as though η were infinite¹¹.

Section I notes that the diamond sector is not a member of the Chamber for labor purposes and has pursued an independent wage policy with stabilization of the nonwhite labor force commencing ten years earlier. To explore the longer term productivity consequences of this stabilization and its implication for the role of white labor, the last two terms of the production

function, (2) are replaced by $T \cdot (\beta_{\tau} \cdot b \cdot t + \lambda_{\tau} \cdot \ell \cdot t + \beta \lambda_{\tau} \cdot b \cdot \ell)$ where T is now a dummy for the post 1964 period and t measures time. Thus, λ_{τ} and β_{τ} reflect progress in productivity of white and nonwhite labor with the passage of time and gaining of experience under stabilization, $\beta \lambda_{\tau}$ reflects any shift in labor substitutability after diminution in job barriers. In addition, the possibility of exploitation of monopoly power by DeBeers warrants incorporation. Thus, if δ represents the elasticity of demand for diamonds, rearrangement of the first order conditions for nonwhite and white labor in diamonds provides, in the quadratic case:

$$11. \quad b = \frac{-\beta}{\beta\beta} + \frac{1}{(1+1/\delta) \cdot \beta\beta} \cdot \frac{w}{\rho} - \frac{\beta\lambda}{\beta\beta} \cdot \ell - \frac{\beta\kappa}{\beta\beta} \cdot k - \frac{\beta\epsilon}{\beta\beta} \cdot e + T \cdot \left[\frac{-\beta_{\tau}}{\beta\beta} \cdot t - \frac{\beta\lambda_{\tau}}{\beta\beta} \cdot \ell \right]$$

$$\ell = \frac{-\lambda}{\lambda\lambda} + \frac{1}{(1+1/\delta) \cdot \lambda\lambda} \cdot \frac{v}{\rho} - \frac{\beta\lambda}{\lambda\lambda} \cdot b - \frac{\lambda\kappa}{\lambda\lambda} \cdot k - \frac{\lambda\epsilon}{\lambda\lambda} \cdot e + T \cdot \left[\frac{-\lambda_{\tau}}{\lambda\lambda} \cdot t - \frac{\beta\lambda_{\tau}}{\lambda\lambda} \cdot b \right]$$

Estimates of equations (9), (10) and (11) are discussed in section IV, but first a few brief notes on the data are in order.

III. The Data

The model is estimated on annual data from 1946 to 1980. Space does not permit a full discussion of the sources and compilation of data assembled for this study, however a few words are in order.

Output by each of the subsectors is measured in physical terms (ounces of gold, 1000 carats of diamonds and tons of coal). For the other minerals, a quantity index is adopted -- actually several published Divisia indices spliced together -- with base in 1957 at 1000. Employment is simply the average numbers at work during the year. The two types of capital stock -- k and e -- are measured in constant, 1970 1000 Rands. The stock figures are derived from gross expenditures deflated by the South African cost of living index, with k depreciated linearly at 4 per cent, e at 10 percent. k incorporates mining property, shafts and mine development, and e is simply equipment. Wages are measured by earnings per employee per year. Output prices are derived from realized value of sales divided by sales -- Rands per ounce of gold, per carat of diamonds, per ton of coal and 1000 Rands per index unit of output for other minerals. The South African, nonwhite, male labor force is proxied by the nonwhite, male population ages 18 to 49, measured in millions of men. The expected wage in manufacturing is then nonwhite employment in manufacturing, construction and South African Railways and

Table 1. Nonwhite Labor Input Equations

	Quadratic				Translog		
	Gold	Coal	Diamonds	Other	Gold	Coal	Diamonds
Intercept	154538 (2.00)	53835 (9.28)	-5113 (1.67)	11319 (0.74)	6.83 (2.46)	9.88 (10.40)	.563 (0.32)
Wage term			-118 (5.94)	-14850 (2.70)			-.0017 (2.37)
Wage term pre '74	-8774 (2.43)	-139 (2.63)			-2.73 (1.74)	-1.82 (1.85)	
Wage term post '74	-2647 (1.50)	-1.60 (0.03)			-.424 (1.11)	-1.34 (1.29)	
Post '74 dummy	-74207 (2.41)	-18136 (1.75)		12519 (1.68)	-.217 (1.71)	-0.43 (0.23)	
White labor	2.27 (1.53)	5.32 (11.35)	3.55 (3.60)	11.5 (9.03)	.280 (1.50)	.430 (5.22)	.559 (2.24)
Equipment	-.029 (0.37)	-.051 (2.94)	.101 (3.97)	0.65 (0.67)	-.008 (0.07)	-.136 (2.46)	.266 (2.75)
Fixed capital	.220 (4.56)	-.089 (2.59)	-.113 (3.56)	-.139 (1.09)	.246 (1.56)	-.068 (0.87)	-.062 (0.40)
Time post '64			669 (4.19)				.110 (0.21)
White labor post '64			-2.99 (3.29)				-.024 (0.13)
Lagged dependent variable			.470 (6.08)				.247 (1.22)
Rho	.385	.424	-.001	.816	.419	.457	.614
Standard error of rho	.155	.168	.192	6.46	.148	.162	.189
Number of observations	33	33	33	33	33	33	33

Harbours relative to male labor force, multiplied by annual average earnings of blacks in manufacturing deflated by the cost of food index.

IV. Estimation of the Model

All equations are estimated by three stage least squares using Fair's technique with respect to instrumental variables, unless otherwise noted. The theory suggests that a large number of nonlinear, cross-equation constraints might be imposed on the estimates. However, no such restrictions are imposed here except in the context of hypothesis testing.

a. Monopsony

From the equation for nonwhite labor in (10) it is readily seen that the coefficients on wage before and after 1974 differ only by inclusion of $(1+\eta)/\eta$ in the former, where η is the elasticity of labor supply. If the sector tends towards behavior consistent with an infinitely elastic supply, rather than as a monopsonist, $(1+\eta)/\eta$ should approach one and the coefficients on the two period wage terms become equal. As discussed in section II, this hypothesis is to be tested with respect to the gold and coal sectors, neither the diamond nor other minerals sector having been part of the Chamber for labor purposes. The estimates of nonwhite labor input equations are presented in Table 1, with t-statistics for a zero null-hypothesis presented in parentheses beneath each coefficient.

In each context -- gold and coal, quadratic and translog -- the wage terms have negative estimated coefficients with a larger absolute value in the earlier period. Moreover, in each case except that of coal in translog form, this difference between time periods is statistically significant at more than a 90 percent confidence level.

But to argue that these results reflect exploitation of monopsony power, at least in gold, one must proceed further. Was the supply of labor facing the industry indeed upward sloping in the earlier period before 1974? Table 2 presents an estimate of the overall labor supply equation (7) up to 1974.¹² Although the region as a whole is frequently referred to by the industry as a labor reserve, the estimate of (7) shows an upward sloping supply of labor with elasticity even significantly less than one at a 99 percent confidence level. Merle Lipton (1980, p. 109) notes:

"It had long been argued by the industry that Black peasants have a backward-sloping supply curve . . . they were target

workers . . . The fact that this argument was a convenient rationalization for low wages was nowhere more clearly demonstrated than by the action of the Chamber, in the wake of the gold price rise, in raising wages to increase supply."

The result in Table 2 is certainly consistent with Merle Lipton's view. Furthermore, the estimate of η reported in Table 2 is not significantly different from that implied by the estimated nonwhite labor input equations for gold, when η is obtained as a nonlinear transformation of the wage coefficients in the two periods. (Berndt et al, (1974))

But this latter derivation of η and indeed the prior tests for monopsony are founded on the theory that the coefficients in Table 1 on the wage term after 1974 equal $\beta\beta$. This may be tested directly by viewing the production functions, and estimates for the case of gold are shown in Table 3.¹³ Therein, both the translog and quadratic estimates provide a negative coefficient on the square of nonwhite labor. Following the Gallant and Jorgenson (1979) test for nonlinear, cross-equation restrictions, this production function estimate of $\beta\beta$ is not significantly different from the implied value estimated in the nonwhite labor input equation.

All of the evidence is thus consistent with exploitation of monopsony power, at least by the dominant gold sector, before 1974. Indeed, this seems eminently sensible, providing a rationale for the centralized system of recruiting and imposition of the maximum permissible average wage payable by member mines, as outlined in Section I. In addition, the recruiting system appears to have provided the mining industry with an ability to respond quickly to changing situations. Thus, if lagged dependent variables are inserted in the nonwhite labor equations for gold and coal, the flexible accelerators prove statistically indistinguishable from zero and these terms are consequently omitted from the equations reported in Table 1. In contrast, the combination of up to two year contracts plus the master and servants laws, prohibiting legal quitting, have rendered the ability of workers to adapt to changing conditions very sluggish. The coefficient on the lagged dependent variable in the overall labor supply equation in Table 2 is, thus, not only significantly positive but indeed very large.

b. Preference for domestic labor

In (10) a negative coefficient ϕ on the post 1974 dummy represents a preference not to rely on foreign workers. In Table 1, this coefficient is estimated to be significantly less than zero at a 95 percent confidence level

Table 2. Nonwhite Labor Supply Equations

	Foreign and Domestic Labor 1948 - 1973	South African Labor 1947 - 1978
Intercept	-3.22 (2.86)	1.97 (1.70)
Log wage	.140 (4.12)	.498 (3.69)
[11 principal component terms for shifts in supply].	---	
Expected wage in industry		-46.0 (2.31)
Labor force		.0303 (1.74)
Lagged dependent variable	.848 (29.78)	.726 (6.81)
Durbin's h statistic	0.18	0.92
Number of observations	26	32

Table 3. Production Functions

	Gold		Diamonds	
	Quadratic	Translog	Quadratic	Translog
Intercept	-.14*10 ⁹ (1.16)	-1055 (1.62)	-121962 (1.77)	-677 (0.58)
Nonwhite labor	-755 (1.39)	-257 (1.89)	4.21 (2.55)	261 (2.61)
White labor	9417 (1.61)	340 (2.07)	48.6 (1.24)	-4.35 (0.01)
Capital	331 (1.41)	229 (2.10)	-.111 (0.35)	41.1 (1.94)
Equipment	-158 (0.48)	-101 (1.61)	.313 (0.38)	-146 (2.31)
Nonwhite*white	.032 (2.78)	34.7 (3.32)	-.001 (0.90)	11.3 (0.86)
Nonwhite*capital	.00084 (2.08)	20.8 (2.84)	-.25*10 ⁻⁴ (1.86)	-1.21 (0.63)
Nonwhite*equipment	-.0012 (1.91)	-15.5 (2.59)	-.54*10 ⁻⁴ (2.22)	-3.38 (0.62)
White*capital	-.010 (1.64)	-31.2 (2.45)	.18*10 ⁻³ (1.53)	2.18 (0.59)
White*equipment	.010 (1.17)	19.1 (2.20)	-.13*10 ⁻⁴ (0.07)	.474 (0.06)
Capital*equipment	.00048 (1.49)	14.6 (2.56)	-.20*10 ⁻⁵ (0.43)	-4.22 (3.02)
Nonwhite ²	-.0011 (1.48)	-7.63 (1.38)	-.29*10 ⁻⁴ (0.46)	-16.2 (3.50)
White ²	-.204 (2.51)	-28.4 (2.98)	-.005 (0.96)	-7.65 (0.35)
Capital ²	-.00023 (1.94)	-12.8 (2.86)	-.15*10 ⁻⁵ (1.41)	-.145 (0.39)
Equipment ²	-.00023 (0.88)	-3.98 (2.22)	.11*10 ⁻⁵ (1.40)	10.4 (4.06)
Dom. lab. post '74	-24.1 (1.82)	-.242 (2.05)		
Post '74 dummy	-.17*10 ⁷ (0.55)	2.74 (1.88)		
Nonwhite*time post '64			.092 (8.20)	2.64 (5.10)
White*time post '64			-.265 (5.01)	-2.96 (4.74)
Nonwhite*white post '64			-.14*10 ⁻³ (2.56)	-.042 (0.82)
Durbin-Watson statistic	2.13	2.16		
Rho			-.311	-.669
Standard error of rho			.231	.273
Number of observations	33	33	33	33

in both formulations for gold, and for coal in the quadratic case. Indeed, the effect is quite large. Thus, the quadratic estimates suggest that despite the escalated wages of this period, the gold sector would have wanted to employ some 70,000 more nonwhites and coal nearly 20,000 extra, as mineral prices rose, had a policy of switching to domestic labor not been pursued. In contrast, the other minerals sector, being outside of the centralized policies of the Chamber, if anything significantly raised their nonwhite labor use in this same period, the coefficient on the post 1974 dummy being positive for that sector¹⁴.

As noted in connection with (10), if additional domestic labor could be hired without raising the wage or lowering productivity, it could not be argued that a policy of reliance on domestic labor is costly to the industry. However, the production function estimates for gold in Table 3 indeed show a significant decline in productivity after 1974 as the labor force becomes increasingly South African. Far from increasing productivity, as intended with a policy of diminished turnover, the replacement of skilled foreign workers by inexperienced South African novices proved costly. It was also costly in terms of wages, for the estimated supply equation for South African labor, in Table 2, again displays a significant upward slope with respect to mine wage. That estimate also brings out the role of the aspiration for a far better paying wage in industry in promoting reluctance to commit to the indignities of mine work, at least until 1978. Thereafter, compulsory relocation in the homelands has resulted in an excess supply even of South African workers for the mines.

c. White and nonwhite labor

Thus, the movement toward localization of the nonwhite labor force adversely affected productivity in gold, though some mining houses clearly hoped stabilization would enhance skill levels. On the other hand, in the diamond sector, erosion of the job color bar after 1964 and reduced turnover of the nonwhite labor force proved more successful. From the production functions for diamonds in Table 3, it is seen that the productivity of nonwhite labor is estimated to have a significant upward trend after 1964. This is also supported by the upward trend in the demand for nonwhite labor, at least in the quadratic case in Table 1¹⁵.

But concurrent with the rising productivity and demand for nonwhites in diamonds was a decline in both for whites. The coefficient on the white

labor_xtime interaction after 1964 is significantly negative in the production functions of Table 1, as is the corresponding time effect in the white labor input equation in Table 4. It seems the erosion of the job color bar indeed had precisely the effects on white labor the Mine Workers' Union has always feared. Thus, in the production functions, the coefficient on the nonwhite_xwhite labor interaction after 1964 proves negative though significantly so only in the quadratic case. With this the nonwhite labor input equations are quite consistent, but not those for whites. It seems at least overt displacement of white labor by nonwhite hiring may have been successfully resisted despite productivity implications.

Indeed, from both Tables 1 and 4, the hiring of white and nonwhite labor is estimated to have been complementary across all sectors¹⁶. With tight maintenance of job delineation between races, additional nonwhite labor has required extra whites in supervisory and skilled posts rather than displacing them. It is also interesting to note that white labor has been a quasi-fixed factor for all sectors, in the sense that the flexible accelerator terms are positive, reflecting a significant difficulty in rapidly adjusting the white labor contingent. In contrast, as noted earlier, the centralized recruiting and prevention of worker organization have permitted far greater flexibility for the mines in adapting the nonwhite labor force numbers. To this, there is an exception in diamonds, where the lagged dependent variable term for nonwhites proves positive though lower than for whites. It seems that one cost to stabilization in diamonds has been a reduced ability or willingness rapidly to transform employment of nonwhites.

d. Monopoly in diamonds and wage discrimination

No support is found in the data for either a hypothesis of concern for monopoly in labor application to diamonds or of wage discrimination against nonwhites elsewhere.

The estimated coefficients on the wage terms in the labor input equations for diamonds embody three components: the expression involving the elasticity of demand for diamonds, δ ; the productivity elements, $\beta\beta$ or $\lambda\lambda$; and the flexible accelerator terms. The critical expression $d=1/(1+1/\delta)$ may, however, be isolated by imposing nonlinear cross-equation and within-equation restrictions on the other two components. Note that d approaches one from above as δ tends toward minus infinity. A null-hypothesis of behavior as if product demand were perfectly elastic may therefore be tested by means of a

Table 4. White Labor Input Equations

	Quadratic				Translog			
	Gold	Coal	Diamonds	Other	Gold	Coal	Diamonds	Other
Intercept	10121 (1.74)	419 (0.38)	959 (2.27)	1966 (1.02)	4.31 (2.84)	-4.82 (3.36)	-.469 (0.41)	.068 (0.06)
Wage term	-22.3 (4.24)	-1.14 (5.11)	-.008 (0.02)	-77.7 (1.45)	-.410 (2.37)	-.870 (2.97)	-.0001 (0.32)	-.0004 (0.51)
Nonwhite labor	.011 (0.83)	.086 (5.89)	.006 (0.43)	.063 (9.32)	.105 (0.85)	.818 (5.52)	.169 (2.93)	.534 (6.79)
Equipment	.004 (0.52)	-.005 (2.15)	-.010 (1.91)	-.007 (0.73)	.165 (2.38)	-.019 (0.45)	-.023 (0.40)	.074 (0.77)
Fixed capital	-.006 (1.18)	.005 (0.99)	.025 (6.92)	.023 (2.51)	-.308 (3.75)	-.082 (0.98)	.403 (6.97)	.152 (1.92)
Time post '64			-111 (8.17)				-1.28 (7.07)	
Nonwhite labor post '64			.135 (8.22)				.387 (7.00)	
Lagged dependent variable	.799 (5.86)	.511 (5.13)	.694 (6.44)	.228 (1.86)	.671 (5.55)	.671 (4.60)	.418 (3.51)	.046 (0.33)
Rho	.316	.039	-.521	.866	.420	.140	-.319	.686
Standard error of rho	.188	.186	.165	.148	.201	.130	.180	.150
Number of observations	33	25	33	33	33	25	33	33

Gallant-Jorgenson chi-squared test on the change in sum of squared residuals when $d=1$ is imposed. In no case -- white or nonwhite, quadratic or translog -- does the estimate of d prove significantly greater than one. At least from this simple specification there is thus no evidence to suggest labor hiring has been restricted in diamonds for fear of depressing the world price of diamonds. Certainly DeBeers does limit diamond sales at times when there is downward pressure on prices, but it is interesting to note that the correlation coefficient for the first differences in physical sales and production of diamonds in South Africa is only .61 over the sample period. It seems at least temporary restricted sales for price support result in increased stock-piling rather than reduced production. To some extent this may be precisely because of the difficulties of quickly adjusting the labor force as emphasized by our estimates. In addition, DeBeers has the option of reducing their scale of production outside of South Africa and may have been more reluctant to make such adjustments within their South African operations.

Lastly, consider the possibility of wage discrimination against nonwhites in addition to the job barriers embodied in the production functions. One way to model such potential discrimination is to envision the mines hiring as if this imposed some implicit psychic cost, c , for each additional nonwhite hired. Thus, c would be added to the right-hand side of equations (3) and (3'.i). To the estimated nonwhite equation in (10) this would add a term $c/(p \cdot \beta\beta)$, (multiplied by b/q in the translog case). If the nonwhite labor equations for gold, coal and others are re-estimated including such a term, the resulting value of $c/\beta\beta$ is significantly negative only in the quadratic case for coal and even there fails a 5 percent one tail test. There is thus no systematic evidence of wage discrimination against nonwhites from this simple test, though obviously job discrimination is quite overt under the apartheid structure.

V. Some Closing Remarks

Despite the popular notion that much of southern Africa formed a vast labor reserve for the South African mines -- a traditional surplus labor economy -- the supply curve on which the industry operated has been shown not only to be upward sloping with respect to mine wages of nonwhites but indeed inelastic. In the period 1946-74, the Chamber of Mines took significant advantage of this -- principally through the dominant gold mining sector -- to exploit its monopsony power. By the mid 1970's rising mineral prices

permitted sharp wage increases motivated by a desire to stabilize the labor force (in the sense of reducing turnover) and by vehement public criticism of the "starvation wages" previously paid. The rising wages attracted more South African workers and on their supply curve the industry has continued to act as a monopsonist. In this later period, foreign labor has been in excess supply and a significant preference not to rely on foreign labor has been demonstrated. Such a preference is not irrational from the mining industry's perspective given the political uncertainties of the region as, for example, FRELIMO displaced the cooperative Portuguese in Mozambique and Malawi's labor was temporarily withdrawn entirely. But stabilization of the South African labor force has not, thus far, resulted in significant productivity gains, rather the foregoing results suggest diminished productivity as South African novices increasingly displaced experienced foreign miners. Moreover, black mine workers have now succeeded in achieving a greater degree of organization, previously thwarted by the mines precisely by maintaining diversified options on foreign labor.

The job color bar, despite limited liberalization of job tasks, has been protected by the apartheid laws partly under instigation from the Mine Workers' Union. Thus, maintenance of this bar has meant that black and white labor have acted as complementary factors, and barring nonwhites from skilled positions helped to support the twenty fold white - nonwhite earnings ratio as of 1970. To what extent the mining houses acquiesced in this legislated job discrimination remains unclear. Certainly the apartheid structure has imposed costs on the mining industry, some negotiated erosion of job barriers has occurred, and no evidence of wage discrimination by the mines is discerned, superimposed on the obvious job discrimination.

To much of this the diamond sector is an exception. Pursuing an independent wage policy since the mid 1960s the diamond sector has stabilized its nonwhite labor force, eroded the skill barriers and largely dispensed with the mine compound living quarters. Both the particular need for security and the personal involvement of Harry Oppenheimer are commonly cited as instigating factors in this transition. The result has been a significant rise in nonwhite labor productivity and a simultaneous decline in productivity of whites, though overt displacement of white miners seems to have been successfully resisted. An additional consequence for the diamond sector is an estimated flexible accelerator on nonwhite labor input more in line with that on white labor throughout the industry, reflecting the slower response in

adjusting any stabilized labor force. Elsewhere the industry has shown greater swiftness in adjusting, via the recruitment network, its nonwhite labor force as demand conditions shifted -- far more swiftness than permitted to labor supply bound by irreversible contracts under the master and servants acts.

Since 1979 even South African labor has been in excess supply following an outward shift in the supply curve induced by compulsory population relocation in the homelands. Today, the Chamber is in consequence split between those mining houses who wish to raise nonwhite wages further and those who argue for real wage reduction, both realizing lower wages would stimulate more employment. To go their separate ways would, according to interviews with industrialists, effectively break the Chamber and the Chamber is vital not only for labor purposes but for such activities as lobbying for tax positions. That the diamond sector could pursue its own wage policy while remaining a Chamber member for other purposes is attributable to the negligible size of its labor force. Government has generally encouraged the recent wage increases, but while concerned with the risks inherent in mass unemployment in the homelands, they would prefer to see employment created around the peripheries of the homelands than in mines located too close to the exclusive white environs.

The future of this labor market -- historically of major importance to several of the labor supplying countries for employment, foreign exchange and income -- is very uncertain. Even if the South African internal political structure remains intact for some years, much will depend on future mineral prices and the value of diamonds and gold have recently, substantially declined. From 1979 onwards, TEBA has maintained a target of 60 percent local 40 percent foreign labor. Some observers predict the foreign component will decline. If so, Lesotho is likely not to experience substantial cuts, for as with the homelands there is fear of creating pockets of mass unemployment and poverty within the frontiers of South Africa. The proportions in which the other labor sending countries would be cut would probably depend on their political conduct vis-a-vis South Africa. Indeed, it will be interesting to see if there may even be revival in Mozambique recruitment, now that a new, inter-governmental understanding has been signed with South Africa.

Footnotes

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¹"Nonwhite" comprises those designated black, colored and Asian. The term "domestic" or South African includes the several Black States or homelands, such as Transkei and Bophuthatswana.

²See Wilson (1972), Breytenbach (1979) and Lipton (1980).

³"Section 10" refers to section 10 of the Bantu Urban Areas Act of 1945, which prohibited blacks from remaining in the "white" areas for more than 72 hours unless they had resided there continuously since birth, had worked continuously for the same employer for 10 years, or for more than one employer for 15 years. See Lipton (1980), who reports that 42 percent of black workers have section 10 rights.

⁴Lipton (1980) uses the term stabilize in this context to mean to settle permanently with one's family. The industry's interest in this form of stabilization is far more ambivalent.

⁵The operations in which Anglo American was involved in the Zambian copper belt had their labor force localised and stabilised some 10 years before the turning point in South Africa. See Daniel (1979).

⁶In the first eleven months of 1981, 15.88 percent of all TEBA recruits were novices, but for no foreign country did this rate exceed 10 percent and for Mozambique and Malawi it was less than 1 percent. Given the obvious, excess supply of foreign novices, this strongly supports the notion of bias against foreign dependence. Indeed, the stated industry policy is to take no Mozambican novices for fear of political activism in the mine compounds.

⁷In addition, complications arising from exhaustible resources are suppressed for simplicity, which is relatively justifiable in view of the massive reserves of most minerals.

⁸Since foreign labor is in excess supply and hence infinitely elastic at the going wage, an objective function for the sector consistent with (3'.ii), omitting white labor and capital for brevity, would be:

$$\Omega = p \cdot Q(f, s) - w(s) \cdot (f + s) - \Psi \cdot f.$$

In other words, the mining houses act as if the cost of hiring foreign labor exceeds the wage rate by an amount Ψ per foreigner.

⁹The 23 underlying variables are: population and rainfall in Botswana, Lesotho, Malawi, Mozambique (rainfall excluded), South Africa and Swaziland; the expected domestic wage in Botswana and Lesotho, the price of maize, cotton and tobacco in Malawi; plantation employment, industrial employment and wage, and marketed crops in Mozambique; employment and wage for blacks in South African manufacturing; and a dummy for independence of Malawi. The demand model presented in this paper is part of a larger study incorporating also the supply side of the story, in which these 23 variables receive explicit treatment. See Lucas (1983).

¹⁰See Nadiri and Rosen (1973). Extension to a nondiagonal matrix of coefficients therein proposed or to decision making when lags are constraints, as in Yoshikawa (1980), is left for later work.

¹¹In the post 1974 period, the other minerals sector has continued to follow the wage leaders partly for the same reasons which motivated the initial raises by the Chamber (particularly in those mines within the other minerals sector owned by the large mining houses), partly because many of these mines lacked the organization to recruit foreign labor and local labor required higher wages.

¹²This estimate is obtained by two-stage least squares, using Fair's technique. The equation includes 11 principal component terms in the vector X , selected by backward stepwise regression, not explicitly shown in Table 2.

¹³No correction for first-order serial correlation is made in these estimates. If ρ , a serial correlation coefficient, is estimated, the associated t-statistic for a zero null-hypothesis is 0.57 for the quadratic case and 1.07 for the translog.

¹⁴No estimate of the translog nonwhite labor input equation is reported for the other minerals sector owing to a high level of collinearity encountered.

¹⁵The sale price of diamonds is quite volatile. The estimated labor input equations therefore deflate wage by price lagged one period.

¹⁶The white labor equations for the coal sector omit the years prior to 1956. During 1955, the Mine Workers' Union demanded and received a sharp pay increase in coal. The bargaining position of the Union was strengthened by a perceived white labor shortage in coal prior to this and the industry responded by intensified training and recruiting of whites, with significant increased immigration of European trainees. By 1956, the Chamber Annual Report (1957) notes an easing in the shortage of European personnel.

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