HOUSING AND PRODUCTIVITY: CAUSALITY AND MEASUREMENT[1]

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Identifying the causes of changes in labor productivity, and measuring their magnitude, is a challenging research task. Even under conditions approaching those of the laboratory, the task is full of booby-traps. Observed changes may be the result of changes in personnel policy, the level or structure of wages, general or specific employee attitudes toward work, types of incentives, working conditions on the job or living conditions off the job, training or other educational programs, the demand for output or the availability of overtime work, the quantitative and qualitative supply of labor or of other factor inputs, any of which may be irrelevant to the postulated cause and exogenous to the measurement. Were the changes random? Or, could they be the result of other forces not identified in the problem?

The problems associated with accurate identification and measurement are compounded when important changes occur in the living environment rather than at the place of work. That changes in the employee's home environment, in contrast to changes at the work site, may bear on his ability to produce, constitute the subject of concern in this paper. Broadly, it is postulated that qualitative improvements in housing and community facilities affect productivity in the same fashion as improvements in working conditions. This paper narrates the difficulties of assessing this more subtle of the two broad classes of factors improving productivity.

The paper is divided along three lines: first, a description of the research design including a statement of facilitating assumptions; second, a test of the direction of causation; and finally, an estimate of the magnitudes of the changes in productivity induced by changes in the quality of housing. Evidence is provided from a case study of the relocation of Korean mine workers to a new community consisting of housing and related facilities.

The Research Design

A test site located in a remote section of South Korea was selected for this case study since the working and living conditions were close to ideal for research of this type. During the three-year period studied, new housing and a limited complement of community facilities were provided for 500 (44%) of the coal miners employed in Hambaek Village. The relative isolation of the new community to the old area permitted a neat division of the employees into a test group consisting of the rehoused for comparison with a control group of workers remaining in old quarters. The test and control groups each comprised 50 members selected at random from the rehoused and non-rehoused respectively.

The mine had been in continuous operation since mid-1955, eight years before relocation of the labor force. Plant records of the government-owned operation yielded productivity data covering a year prior to relocation and two years following.

Causality could only be determined with a four-cell "before-after/with-without" framework. For example, a cross-sectional analysis comparing the performance of a test group with that of a control group might demonstrate that the performance of rehoused workers was superior; yet, the conclusion fails on the grounds that the more productive may have enjoyed superior ability to pay for better residential accommodations. Hence, causation could run in either direction, from greater productivity to better housing, or the obverse. Moreover, a before-after comparison based solely on a group of rehoused workers could obscure any changes in non-housing factors, any of which might bear on productivity. For example, labor productivity could increase merely from familiarity gained by the repetition of work tasks, or any of the other factors listed earlier. Such influences, exogenous to this measurement problem, would be revealed in the records of a control group subject to all of the same influences except the one under consideration.

Our four-cell analytical framework permits comparisons of performance differences in three important dimensions:

(1) the test group compared with the control group during the period following the test group's relocation,

(2) the control group with the test group before rehousing to ascertain if the latter's ability to pay for qualitatively superior housing exceeded, or merely equaled, the former's, and

(3) the test group's performance after rehousing compared to before.

If output was machine-dictated, if employees were hired to work for a certain short time period without regard for output, or if there were no production incentives, then it would be unreasonable to assume that productivity is functionally related to the workers' energies or motivations, two qualities closely associated with environmental conditions. Although the mine is of comparatively recent vintage, the operation is still labor intensive, a necessary condition for our research design. Further, since transient laborers are not hired, temporary surges in demand are accommodated by overtime work. Finally, incentive wages are paid for output in excess of established norms.

Several other conditions also governed the

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choice of this site. First, except for the notable change in housing quality, working conditions affecting performance remained unchanged over the three-year observation period. Second, because the vast majority of workers had long employment histories at the Hambaek mine, any productivity or skill increases resulting from work repetition were zero or negligible. This assumption was confirmed by the lack of statistical significance in the productivity trend for the year pre-dating relocation, a finding discussed later in more detail. Third, other conditions remaining constant during the observation period were plant and equipment (except for the replacement of equipment as it depreciated), and the wage and organization structure. Our data have been adjusted for across-the-board salary increases, however. Finally, since our information was obtained at the end of the three-year observation period, the knowledge that research was being done on performance could not have biased the data. In sum, all factors bearing on productivity except living conditions remained constant. The performance of the control group supports this general statement.

The new community, constructed with the financial assistance of the Agency for International Development, stands in sharp contrast to previously existing facilities. The 500 dwelling units are qualitatively superior particularly with respect to size, protection from the elements, and the availability of utilities and sanitary facilities. In contrast to the new dwellings, most of the old had neither running water, electricity, nor adequate ventilation. Occupancy intensities were higher by a substantial margin in the old units. On average, the intensities were 4.6 persons per room in the old dwellings against 2.5 persons per room in the new, and the living space per person was 61 square feet compared to 143 square feet in the new housing units. Limited community facilities, consisting of a public bathhouse, a kindergarten with recreation facilities for children, a barber shop and beauty parlor, and a grain distribution center, were also included as an integral part of the development. These structures accounted for about one-third of the total cost of 108.2 million won ($832,300) for the entire project.

Although limited, the community facilities can be considered as a substantial improvement over those available in the old area, where the only bathing arrangement, for example, is the river which also serves as a source of water and destination of sewage. Because the new community facilities are situated a mile distant from the old housing area, it is likely that they serve only the rehoused families and their effect on the productivity of those remaining unrehoused would be negligible. Yet, the journey-to-work distance from the new area was the same as from the old; hence, differences in commuting time or distance were not a factor influencing productivity changes.

The Hypothesis

The hypothesis to be tested is that better housing[2] bears significantly and favorably on labor productivity. The transmission of causation from housing to productivity is via dual channels. It may be reasoned that healthier, more sanitary living conditions affect physical well-being, reduce the incidence of illness, and, with it, the number of days on sick leave, and improve performance on the job. In addition to the physiological effects, the improvement in living standards may have psychological ramifications translating into improved motivation and, in turn, into greater output. The latter channel would be identified in data on output per hour. The two taken together should be indicated by an increase in production over the longer period, say a week. This is the information which serves as the basis for our test.

The most convenient common denominator for measuring heterogeneous output is income from wages and salaries. Income earned is a reasonable proxy for productivity since wages are paid on the basis of piecework and performance level expected. Performance-based rates paid for picking are illustrative. Because upward picking is easier and faster than horizontal picking which, in turn, is easier than downward picking, the least is paid per unit for coal mined by upward picking and the most for downward picking. Similarly, because mining rock formation is slower and more difficult than working in a sand formation, coal picked from rock commands a higher wage. As the wage system compensates for the difficulty of the task, it is a good indicator of labor productivity and a workable proxy for output in physical units. The wage proxy has the further advantage of stating output in commensurable units. The wage dollar earned for picking is comparable to the dollar earned for, say, repair work.

Before testing the hypothesis itself, a digression is in order to reinforce our heroic ceteris paribus assumption; that is, that non-housing factors influencing productivity remained "constant" during the three-year observation period. If the assumption is indeed realistic, then any changes in productivity may be attributed to housing, the only factor not held constant.

The assumption would be acceptable for the year preceding rehousing if output per man remained unchanged throughout that period. Regressing each of the variables, hours worked per week, output per hour, and output per week against time, yields the estimates for the average worker listed in Table 1. Coefficients of determination are omitted as irrelevant since the purpose is to identify a trend rather than to "explain" fluctuations in productivity.

Comparing the regression coefficients with the corresponding standard errors (Table 1), reveals that none of the regression coefficients

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[2] For convenience, the term "housing" will henceforth refer simultaneously to the dwelling units themselves plus the inseparable, but less important, community facilities component.

TABLE 1. TIME TRENDS IN LABOR PRODUCTIVITY PER MAN, YEAR PRIOR TO REHOUSING

Variable	Test Group			Control Group		
	Regression Coefficient of Time	Standard Error of Regression Coefficient	Intercept	Regression Coefficient of Time	Standard Error of Regression Coefficient	Intercept
	During Normal Working Hours					
Hours worked per week	4.24	2.68	2,157.58	5.07	2.56	2,094.33
Output per hour (in won)	-0.06	0.05	54.99	0.06	0.07	55.81
Output per week (in won)	96.49	118.48	118,183.28	139.75	189.06	117,032.82
	During Overtime Working Hours					
Hours worked per week	-1.81	1.66	357.92	-2.39	1.87	368.75
Output per hour (in won)	-0.09	0.05	51.68	-0.06	0.05	50.52
Output per week (in won)	-126.10	88.66	18,802.65	-110.83	97.91	18,432.85

are significantly different from zero at the .05 level. Consequently, the lack of a significant trend points to the absence of factors affecting productivity at least during the year before rehousing. This applies equally to both groups of workers. Heroic as it may be, the ceteris paribus assumption would seem to hold for this period.

If the same holds for the period after rehousing, there should be no significant difference in the control group's average productivity levels after rehousing compared to before. For the test group, however, a significant difference in the before and after levels would support the hypothesis; that is, that the productivity increase could be traced to the housing improvement. Comparing the second year following rehousing[3] with the year before rehousing yields the differences in weekly output during normal working hours listed in Table 2.

TABLE 2. DIFFERENCES IN AVERAGE WEEKLY OUTPUT DURING NORMAL WORKING HOURS, SECOND YEAR FOLLOWING REHOUSING COMPARED TO YEAR PRECEDING REHOUSING

Group	Mean Output (in won earned)	Standard Error
Test Group	34,100	11,000
Control Group	29,000	14,500

Quite clearly as this evidence indicates, the same conditions are no longer applicable, for the productivities of the control group, as well as the test group, each taken in the aggregate, increased significantly. Either of two explanations is plausible. The ceteris paribus assumption fails to apply to the interval following housing; that is, changes of the type noted in the first paragraph of this paper "caused" an increase in the productivity of all workers whether rehoused or not. A second alternative explanation is that better housing has a "demonstration-effect" on the performance of those not rehoused.

Consider the second possibility first. If better housing is popularly accepted as a goal for achievement,[4] and further, if productivity governs progress toward this goal, it follows that workers will be motivated to boost their

[3] The second year following rehousing (or the third year of the observation period) was chosen for this test since, as noted later, the impact of the change in living conditions is not fully realized during the first year.

[4] The rehoused family received gratis a dwelling conservatively "shadow-priced" at a monthly rent value of 500 won for which it forsook a monthly rent subsidy of 300 won paid while they were resident in old company housing. Hence, aside from the prestige of being chosen for relocation in the new project, the rehoused family enjoyed an effective annual standard of living increase netting 2,400 won. As further evidence supporting acceptance of the new units, it should be noted that since the housing project was opened, the management of the mine has been flooded with requests from miners in other districts for transfer to the Hambaek operation.

output levels in order to raise their housing standards. Occupancy policy followed by the housing corporation is relevant here. Although the comparative statistics for test versus control group fail to reveal the difference, productivity was held out as the principal criterion for assigning occupancy priorities to the 1,100 workers seeking a supply of less than half as many dwellings. During the one year prior to rehousing, average weekly output for test and control groups -- 84,513 won and 84,508 won respectively -- was nearly identical. This "hard evidence" indicates that, in fact, those ultimately chosen for occupancy produced no more efficiently than those who were left behind. Aside from the reality, the relevant consideration is that performance was perceived as governing the probability for initial selection for relocation, for maintenance of occupancy once rehoused, or for the opportunity for subsequent rehousing among those left behind.

The alternative explanation for the behavior observed for the control group is that the ceteris paribus assumption is unwarranted during the post-rehousing period. Probing our data further indicates the reverse; that is, non-housing factors in fact remained constant during this period as well. Our support is gained by examining the behavior of earnings paid for overtime work in 1963. As the negative signs of the regression coefficients in Table 1 indicate, average earnings were declining slightly as a result of a decrease in the demand for coal during that year, and a consequent decline in the availability of overtime work. Hence, to account for these conditions, exogenous to the firm and its employees, overtime output is measured in terms of hourly production in order to hold constant the availability of overtime work. Again, comparing the differences between the second year following rehousing with the year preceding rehousing, yields the averages reported in Table 3.

TABLE 3. AVERAGE HOURLY OUTPUT DURING OVERTIME HOURS, SECOND YEAR FOLLOWING REHOUSING COMPARED TO YEAR PRECEDING REHOUSING

Group	Mean Hourly Output		Mean Difference	Standard Error of Mean Difference
	Before Rehousing	After Rehousing		
Test Group	49.321	72.233	22.912	10.391
Control Group	48.932	60.466	11.534	13.765

The differences are readily apparent. For the test group, output per hour of overtime work increased after rehousing by a substantial margin (about 46%). This is not the case for the control group whose increase in hourly output during overtime cannot be considered significant due to the relative size of the standard error, and is thus merely the result of incidental, hence irrelevant, factors.

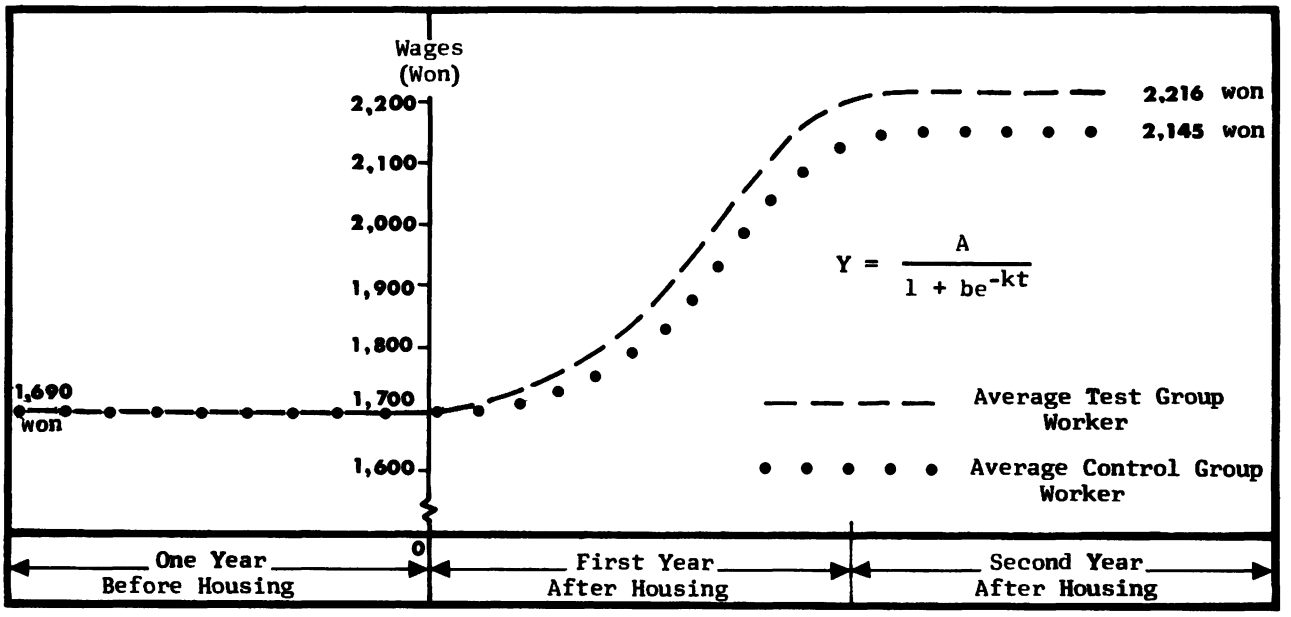
In sum, the ceteris paribus assumption would appear to persist during the post-rehousing period as well as before. If a change exogenous to our problem had been operative -- for example, if the quality of equipment had been improved substantially[5] -- the effects would have shown up in the productivity data for the overtime work of control and test group alike since both would have been affected similarly. That it did not, and that the assumption holds, lends credence to the "demonstration-effect" as the true explanation of the control group's productivity increase during normal working hours. Finally, the analysis of this section demonstrates that qualitative improvements in housing translate favorably and significantly into increases in labor productivity, and that causation runs from the former to the latter.

The Estimates

The best fit for the trend development in earnings, or output per week during normal working hours, for the average worker approximates a logistic curve (Figure 1). As noted, the weekly output of the workers in both groups showed no significant trend during the period before rehousing; that is, output fluctuated around a horizontal line. Moving into the post-rehousing period, output increased very slightly until roughly six months after relocation when output began climbing rapidly followed by a decline in the rate of increase until a maximum or capacity level was reached at roughly the end of the first year following rehousing. Beyond this point, further changes were statistically zero with the level of output maintaining itself on a new plateau. The parallelism between control and test group behavior in the timing of changes gives more credence to the "demonstration-effect" for it suggests the

[5] Examination of company records extending from the start of operations in 1955 to the present indicates that the increase in annual capital investment was no greater during the observation period than in earlier years. For the data, see B. Khing Tjioe and Leland S. Burns, Report on Productivity in Relation to Housing Conditions and Community Facilities in Hambaek, Korea, (Los Angeles, California: International Housing Productivity Study, Real Estate Research Program, Graduate School of Business Administration, University of California, 1966), Table 3.

FIGURE 1. TRENDS OF WEEKLY EARNINGS, AVERAGE TEST GROUP AND CONTROL GROUP WORKERS, ONE YEAR BEFORE AND TWO YEARS AFTER REHOUSING



extent to which the control group members competed with their rehoused counterparts.[6]

For purposes of estimating the quantitative impact of the housing improvements, we shall ignore the one year post-rehousing adjustment period, and focus on experience of the second year. The post-rehousing development of output is best described by a logistic curve of the form,

$$Y = \frac{A}{1 + be^{-kt}} \qquad (1)$$

where Y is earnings, A is the earnings maximum to be estimated, and t is time. The maximum level in weekly output can be described by rewriting (1) and differentiating:

$$be^{-kt} = \frac{A - Y}{Y} \qquad (2)$$

$$\frac{dY}{dt} = \frac{kAbe^{-kt}}{(1 + be^{-kt})^2} . \qquad (3)$$

Substituting (2) in (3) gives

$$\frac{dY}{dt} = \frac{Ak\frac{A - Y}{Y}}{\frac{A^2}{Y^2}} , \text{ or } \frac{dY}{dt} = \frac{k}{A}(A - Y)Y \qquad (4)$$

which leads to

$$\frac{1}{Y} \cdot \frac{dY}{dt} = k - \frac{k}{A} Y . \qquad (5)$$

This means that the relative or percent increase in Y, the left-hand side of (5), is linearly dependent on the absolute level of Y. Both the relative increase in output and the absolute output for the two-year period following rehousing can be determined in order to estimate the parameters of (5). Regression of these variables yields the following for the test and control groups respectively:[7]

$$\frac{1}{Y} \cdot \frac{dY}{dt} = \underset{(0.00624)}{-0.02649}\ Y + 41.9258 \qquad (6)$$

[6] Interestingly, this same pattern has been observed in numerous other cases. See, for example, J. P. Davison, P. S. Florence, B. Gray, and N. Ross, Productivity and Economic Incentives, (London: Allen and Unwin, Ltd., 1958), who conclude from an investigation of the effects on productivity of changes in incentives that "such increases in output, most of them large,... were found not to be just a 'flash in the pan' but were sustained over the whole period of study"(p.203).

[7] The output used in these regressions applies for ten-day periods and is measured in hundreds of wons for each of the whole group of 50 workers.

$$\frac{1}{Y} \cdot \frac{dY}{dt} = \underset{(0.00594)}{-0.02252}\ Y + 34.5051 \qquad (7)$$

(Standard errors appear in brackets below the corresponding regression coefficients.)

From equation (5), the coefficient of Y is $-\frac{k}{A}$. Since A is the output maximum, this level can be calculated as the intercept values, 41.9258 and 34.5051 (=k) for the equations describing test and control group samples, respectively, divided by the corresponding regression coefficients. Adjusting the above to weekly production per man yields estimates of output maxima of 2,216 and 2,145 won per week for the average test group (rehoused) worker and average control group worker respectively. Compared with the pre-rehousing average performance level of 1,690[8] won per week for the average worker in each group, the productivity of the test group increased about 31 percent while the level of the control group increased 27 percent.[9]

Conclusions

The Korea test case has demonstrated that improved living conditions resulted in a significant and sizable positive impact on productivity levels among rehoused workers.[10] In addition, although the benefits of these improvements were not directly shared by the non-rehoused, in their competition for available space these workers also bettered their production records and, with increased incomes, raised their standards of living. Although our data limit us to short-run estimates of both this "demonstration-effect" and the direct productivity increases of rehoused laborers, the trends of the output curves strongly suggest that the jump in production is sustained at a new capacity level over the longer period. This speculation would seem justified, for once families accustom themselves to new, higher standards of living, they generally seek to maintain, if not increase, them further.

A few caveats are in order, however. The extent of broad generalization is always limited when conclusions are based on the evidence of a single case. Unfortunately, this seems particularly true in the context of economic development, an area of inquiry desperately searching for generalized principles but one where they are difficult to attain when behavior is so strongly conditioned by cultural traits indigenous to particular areas rather than common to many. Along the same line, unique factors of this case may account for the phenomena we have observed. For example, were it not for the performance-based occupancy criterion, it seems doubtful whether the "demonstration-effect" would have materialized. The effect could also depend on the number of units built in the project. In other cultures where housing may rank low in desirability, the psychological reactions in the form of motivation may never occur.

The results of other studies of the relationship between housing and productivity, currently in progress, will confirm or modify the conclusions and estimates of magnitude reported here. The purpose of all of these studies is to develop operational framework for evaluating the returns to investment in residential construction in order that housing can compete for scarce development resources on the same basis as alternative investments.

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[8] Obtained by dividing the mid-point of the regression equations for weekly output (Table 1) by 50, the number of sample members per group.

[9] Most likely, the changes are conservative since the maximum productivity estimates of each of the two groups of workers were unfavorably affected by a temporary decline in productivity toward the end of the first year following rehousing.

[10] As we have noted elsewhere, when the benefits are fully counted and priced (most particularly, when the benefits to health are added), the rate of return on this housing investment was attractive and comparable with rates of return earned on capital invested in alternatives. See Tjioe and Burns, op. cit., Section 7.