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HOUSING MARKET: A REGIONAL ANALYSIS

BY

JOHN M. QUIGLEY

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RESIDENTIAL ENERGY STANDARDS AND THE HOUSING MARKET: A REGIONAL ANALYSIS*

by

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February 1984

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I. INTRODUCTION

About one-fifth of total U.S. energy demand originates in the residential sector from the requirements to heat, cool, light, or to provide hot water in residential dwellings. Thus, to a substantial extent, the overall impact on the economy of the dramatic increase in energy prices during the past decade depends upon on the way in which energy is used in the production of housing services. The efficacy of any national or regional "energy policy" imposing standards or mandatory controls in the residential sector depends upon the extent to which increases in energy prices stimulate the natural "conservation" of energy.

Somewhat surprisingly, given the importance of energy in the residential sector and the role of energy as an input into the production of housing services, virtually all studies of energy usage view residential energy as a final consumption good. These "end use" studies estimate the demand for final output, residential energy, subject only to the rather weak Slutsky restrictions of consumer demand theory. In contrast, there are a number of high quality economic and engineering studies of the substitutability of energy for other inputs in the manufacturing sector (see Berndt and Wood, 1979 for a recent review).

This paper focuses on residential energy as an input to the production of flows of housing services. This perspective forms the basis for analyzing the effects of energy regulation upon natural and induced "conservation," the utilization of residential capital, and the well-being of consumers in the housing market.

The model developed in Section II below is estimated using an extensive body of data on some 7,000 newly constructed houses located in six counties in California. The regional aspect of the analysis is potentially important to understanding the effects of regulation in these markets. As is discussed in more detail below, regulations governing new construction recently adopted by the California Energy Commission impose a different set of constraints in sixteen distinct climate regions in the state. Thus, the effects of the regulatory system upon energy consumption and consumer well-being may vary, perhaps substantially, across local markets with differing meteorological and regulatory characteristics.

II. THE ECONOMIC MODEL OF RESIDENTIAL ENERGY UTILIZATION

A. Production

As noted, most models of the energy sector treat residential energy as an object of final demand; most models of housing production concentrate on the substitution between capital and land in the production of real estate (see Halvorsen 1975 for an example of the former and McDonald 1981 for a review of the latter studies).

There are apparently only four studies which treat residential energy or operating expenditures as inputs into the production of services, and only one which considers single detached housing. Muth (1973) estimated factor demand equations for real estate and operating inputs from 32 observations; Oron and Ingram (1977) estimated a production relationship based on 29 observations. Rydell's (1976) and Neels' (1981) analyses of energy and housing production assume, among other things, that the unit prices of capital vary with the characteristics of dwellings.

In this section, we estimate the parameters of a two-level (or "nested") constant elasticity of substitution (CES) production function (see Sato, 1967) relating housing output, that is, annual flows of housing services, to land, capital and operating inputs. The analysis is organized so that it is possible to replicate previous work investigating the elasticity of substitution between capital and land and then to extend this work to include current operating inputs.

The assumed production function is nested in the following sense. First, following most of the literature on housing production (e.g., McDonald, 1981), we assume that land (L) and capital (K) are combined to produce residential dwellings. We call the output real estate (R). Following Muth (1973) and Ingram and Oron (1977), we further assume that real estate and operating inputs (E) are combined to produce the flows of housing services (H) demanded by final consumers.

Specifically, we assume a CES production relationship of the form:

$$(1a) \quad R = \omega \{ \alpha K^{-\rho} + L^{-\rho} \}^{-1/\rho}$$

$$(1b) \quad H = \omega' \{ \alpha' (jR)^{-\rho'} + E^{-\rho'} \}^{-1/\rho'}$$

where ω and α and their primes are parameters, where j is the rate of flow of services provided by stocks, and where the elasticity of substitution between inputs σ , is: $\sigma = 1/(1 + \rho)$

Capital, land, operating inputs, real estate, and housing are measured in physical units. For a given distribution ratio α , the choice of physical units

or a normalization for relative prices affects only the arbitrary normalization factor ω .

We assume that the form of the production function and the elasticities of substitution between factors in production are identical across regions, but that the distribution ratio α may vary with climatic, soil, or topographical conditions, i.e.

$$(2) \quad \alpha = \pi \alpha_i d_i$$

where d_i is a dummy variable with a value of one for observations from region i and zero otherwise.

We assume that the production function is homogeneous of the first degree, implying that the value of the output service flow equals the inputs consumed, i.e.,

$$(3a) \quad jrR = (j+d)kK + j\lambda L$$

$$(3b) \quad pH = jrR + eE$$

where

pH represents expenditures on housing services at price p
 rR represents expenditures on real estate at price r
 eE represents expenditures on operating inputs at price e
 kK represents expenditures on capital at price k
 λL represents expenditures on land at price λ
 d represents the rate of depreciation of capital

The parameters of this production relationship are estimated using information obtained from the sales of newly constructed owner-occupied housing insured under the Federal Housing Administration (FHA) Section 203 mortgage program.

The data consist of observations on home sales and the associated FHA insurance approvals recorded in 6 counties in California from 1974 through 1978, a period during which real energy prices rose by about forty percent. Besides reporting the selling price of real estate (rR) and the closing costs of each transaction, the FHA records indicate the parcel area of the property (L) and an appraisal of the market value of an equivalent site (λL). The latter two elements permit the unit price of the land input to be estimated.

Depreciation (dkK), alternatively, the current expenditures required to prevent depreciation, is measured by the FHA "estimated cost of maintaining the physical elements of the property to prevent acceleration of depreciation and to assure safe and comfortable living conditions (U.S. Department of Housing and Urban Development, 1977, iii)." Operating input expenditures (eE), also calculated by FHA appraisers include "the cost of heating, electricity, gas, water and other items generally known as utilities, excluding those services which are provided under the lien of non-prepayable special assessment which continues indefinitely for supplying water, sewage disposal, removal of garbage or other services necessary for the occupancy of the premises (U.S. Department of Housing and Urban Development, 1977, iv)."

The rental costs of the services provided by real estate, land and capital are computed from information on taxes and mortgage terms. Annual property tax liabilities and the selling price of the property permit the calculation of the effective property tax rate (t). This tax rate, together with the marginal federal tax rate (T) of the purchaser (inferred from household income), the interest rate (i^*) associated with the mortgage, the market interest rate (i) and the loan-to-value ratio (LV) of the mortgage, permit the annual cost of service flows, net of tax advantages, to be estimated:

$$(4) j = [i * LV + i(1-LV) + t] (1 - T)$$

Together, all this information permits annual capital expenditures to be computed from (3a) and (3b).

Table 1 summarizes the raw data on sale prices, expenditures, and input prices for the six counties. The directly observed variables include the selling prices of houses, which averaged between 35 and 43 thousand dollars, the expenditures on land, which averaged between \$9,400 and \$11,600, annual operating expenses, averaging between \$420 and \$720 and six price indices.

From these, using j (computed from equation 4) as the user cost, annual costs of capital and land are computed, as well as the net annual cost of housing services.

The price of capital (k) is measured by the Boeckh Index of the cost of a new standardized frame residential structure exclusive of land, and is compiled from bimonthly information reported by county. The price of operating inputs (e) is estimated by the price index of "fuel and other utilities" compiled by the Bureau of Labor Statistics and reported quarterly, or in some cases monthly, by SMSA.

Competitive equilibrium requires that the ratio of relative input prices equal the ratio of marginal products.

$$(5a) \frac{\partial R / \partial K}{\partial R / \partial L} = \alpha (K/L)^{\rho-1} = (k/\lambda)$$

TABLE 1

Means and Standard Deviations of Variables
On New Home Sales in California
by County

(Standard Deviations in Parentheses)

	Los Angeles (LA)	Alameda (AL)	Contra Costa (CC)	San Diego (SD)	San Bernardino (SB)	Riverside (RI)
Number of Observations	467	908	1050	1051	2237	1312
Real Estate Expenditures, rR	34480.00 (9960.40)	41570.00 (7842.50)	42985.00 (8606.10)	42318.00 (9580.10)	40377.00 (7727.00)	38226.00 (8220.20)
Annualized, jrR	2714.60 (719.72)	3058.00 (562.23)	3174.40 (594.75)	3149.60 (676.36)	2943.10 (555.64)	2815.90 (581.48)
Land Expenditures, lL	9403.30 (3665.20)	11589.00 (3024.70)	10918.00 (3658.60)	11561.00 (3794.90)	11182.00 (3373.70)	10123.00 (3680.20)
Annualized, jλL	741.22 (270.83)	852.07 (218.99)	805.30 (260.83)	860.46 (276.51)	815.36 (245.50)	742.45 (260.52)
Operating Expenditures, Annual, eM	567.52 (116.87)	422.58 (86.33)	438.13 (92.160)	551.55 (136.91)	715.62 (144.43)	722.62 (167.18)
Capitalized, eM/J	7211.30 (1750.20)	5766.10 (1338.40)	5950.20 (1415.40)	7438.80 (2041.10)	9856.60 (2231.80)	9840.80 (2527.70)
Capital Expenditures, kK	20784.00 (8491.80)	23946.00 (5989.60)	26824.00 (6295.50)	26879.00 (7016.00)	24632.00 (5455.50)	23611.00 (5533.20)
Capitalized, jkK	1634.80 (645.97)	1763.70 (439.44)	1984.60 (458.15)	2001.80 (507.10)	1797.80 (401.52)	1745.30 (418.48)

TABLE I

Means and Standard Deviations of Variables
On New Home Sales in California
by County

(Standard Deviations in Parentheses)

	Los Angeles	Alameda	Contra Costa	San Diego	San Bernardino	Riverside
Number of Observations	467	908	1050	1051	2237	1312
Land Price, λ	1.7896 (1.3680)	3.7382 (3.1632)	2.5787 (2.6132)	2.6224 (2.0336)	1.6941 (.7071)	1.7190 (1.1646)
Capital Price, k	7.6513 (0.8998)	7.3393 (0.4982)	7.7645 (0.8408)	7.3685 (0.7287)	7.6472 (0.6142)	7.7576 (0.6374)
Fuel Price, e	1.6142 (0.0876)	1.5350 (0.1144)	1.6185 (0.1790)	1.5053 (0.0892)	1.6198 (0.0521)	1.6280 (0.0552)
Interest Rate, i (%)	8.5200 (0.5200)	8.0100 (0.3600)	8.1500 (0.4400)	8.3400 (0.4500)	8.2800 (0.3800)	8.3700 (0.4500)
Property Tax Rate, t (%)	2.5300 (0.4500)	2.5000 (0.3100)	2.4500 (0.3500)	2.2000 (0.4500)	2.1400 (0.3000)	2.1700 (0.5700)
Cost of Capital Services, j (%)	7.9500 (0.6300)	7.3800 (0.5800)	7.4300 (0.6200)	7.5000 (0.6900)	7.3200 (0.5800)	7.4200 (0.7200)

$$(5b) \quad \frac{\partial H / \partial (jR)}{\partial H / \partial E} = \alpha' (jR/E)^{\rho'-1} = (r/e)$$

or equivalently

$$(6a) \quad \text{Log} \left(\frac{kK}{\lambda L} \right) = \sigma \log \alpha + (1-\sigma) \log (k/\lambda)$$

$$(6b) \quad \text{Log} \left(\frac{jR}{eE} \right) = \sigma' \log \alpha' + (1-\sigma') \log (r/e)$$

The price of real estate (r) is not directly observed. However, it is possible to estimate σ and α from equation (6a) without reference to r . With these results, competition implies that r can be computed directly as the marginal cost of real estate output:

$$(7) \quad r = [\alpha^{\sigma} k^{1-\sigma} + \lambda^{1-\sigma}]^{1/(1-\sigma)}$$

Table 2 presents estimates of the substitution between capital and land in the production of real estate, estimated from the regression of the logarithm of expenditure shares ($kK/\lambda L$) on the logarithm of relative prices (k/λ). The regressions explain 25-29 percent of the variation in the dependent variable.¹ Column i presents the simplest model, identical in form to (6a). In column (ii) the distribution ratio α is permitted to vary for each of the six counties (presumably reflecting topological, soil, and other variations), but the elasticity of substitution is constrained to be the same.²

As described previously, the data underlying the analysis consist of new dwellings sold during the 1974-1973 period. During this period, it is certainly

¹ In these regressions, the ratio of price indices is scaled to an average sample value of about one.

Table 2
ESTIMATES OF FACTOR SUBSTITUTION IN
THE PRODUCTION OF REAL ESTATE

Pooled Model Across California Counties

$$R = [(\pi \alpha_i d_i) K^{-\rho} + L^{-\rho}]^{-1/\rho}$$

7025 Observations
(t ratios in parentheses)

Coefficient	Variant			
	i	ii	iii	iv
1 - σ	0.266 (47.88)	0.291 (49.83)	0.270 (48.12)	0.291 (49.83)
$\sigma \log \alpha_0$	0.780 (216.74)		0.823 (83.81)	
$\sigma \log \alpha_{AL}$		0.809 (86.83)		0.810 (69.46)
$\sigma \log \alpha_{CC}$		0.867 (100.93)		0.869 (70.76)
$\sigma \log \alpha_{LA}$		0.653 (50.29)		0.655 (39.12)
$\sigma \log \alpha_{RV}$		0.762 (94.82)		0.714 (58.13)
$\sigma \log \alpha_{SB}$		0.712 (114.62)		0.714 (58.13)
$\sigma \log \alpha_{SD}$		0.852 (100.00)		0.854 (69.23)
-T			-0.015 (4.72)	-0.001 (0.20)
R ²	0.246	0.287	0.249	0.287
F-test*		79.98		75.30

Note: d_i is a dummy variable with a value of one if an observation is from county i , and zero otherwise.

*test of the hypothesis that: $\alpha_i = \alpha_j = \alpha_0$

possible that technical change, spurred by relative price changes, increased the efficiency of housebuilding. If any such technical change is non-neutral, the marginal physical products of land and capital, equated by competitive forces to input prices, should be expressed in comparable efficiency units across time periods. Table 2 tests one formulation of this dynamic, namely an exponential augmentation of factor inputs over time (τ)

(i.e., $L(\tau) = L_t \exp [g_L \tau]$, $K(\tau) = \exp g_K \tau$) where L and K are measured in efficiency units and g_L and g_K are the rates of factor augmentation). Substitution of these expressions into (5a) and rearranging yields

$$(8) \quad \frac{kK}{\lambda L} = \sigma \log \alpha + (1-\sigma) \log (k/\lambda) - \Gamma \tau$$

where Γ is $(g_K - g_L)$ and $\Gamma = 0$ represents Hicks neutral technical change.

² Clearly housing production is a putty-clay process in the sense that, once constructed, structures are expensive to modify. This suggests that, if prices are expected to vary over time, marginal products will be equilibrated to some average of expected future prices over the lifetime of the structure (T). For example, if prices are expected to increase exponentially

(i.e., $k(\tau) = k \exp [g_K \tau]$, $\lambda(\tau) = \lambda \exp g_L \tau$), then the right hand side of (5a) is

$$\left(\frac{k}{\lambda}\right) \frac{(1/T) \int_0^T e^{g_K t} dt}{(1/T) \int_0^T e^{g_L t} dt} = \frac{k}{\lambda} \left[\frac{g_L}{g_K} \left\{ \frac{e^{g_K T} - 1}{e^{g_L T} - 1} \right\} \right]$$

Since the term in the square brackets is a constant, this affects only the intercept in equation (6a). For example, if capital prices were expected to increase by ten percent per year, then if buildings were expected to last 40 years, the term in the square brackets would be about .07. The estimate of σ derived from (6a) by ignoring these expectations would be identical, and the expectations would be reflected in the regression estimate of α .

The last two columns of table 2 present the regression estimates when this is incorporated into the model. The estimate of Γ is small and statistically insignificant in the more general model. The sign of the coefficient indicates capital saving technical change during the period.

Table 3 presents estimates of the relationship between real estate and operating inputs in the production of flows of housing services. The simple models explain less than twenty percent of the variation in factor shares. When the distribution ratio is permitted to vary for different counties (presumably reflecting weather, wind, and climate variations), the explained variance of the model exceeds fifty percent.

As expected, the elasticity of substitution, about 0.3, is much smaller than the capital-land substitution parameter. The distribution parameter is substantially higher. This, too, is to be expected, since carrying costs are typically substantially larger than operating costs.³ There appears to be more variation in the distribution ratio across counties, perhaps reflecting more substantial differences in climatic conditions affecting energy usage. When the model is amended to incorporate dynamics, the substitution parameter is virtually unchanged. When the model is disaggregated to include county variations, the estimate of technical change (during an admittedly short period) is not significant.

B. Demand

As is well known, housing market transactions provide observations on real

³ Again, the ratio of relative prices is scaled to an average sample value of about one. As noted in footnote 2, the higher value of the distribution ratio may also reflect market expectations of continued increases in energy and other operating costs over the planning horizon.

Table 3
ESTIMATES OF FACTOR SUBSTITUTION IN
THE PRODUCTION OF HOUSING SERVICES

Pooled Model Across California Counties

$$H = [(\pi \alpha'_i d'_i) R^{-\rho'} + E^{-\rho'}]^{-1/\rho'}$$

7025 Observations
(t ratios in parentheses)

Coefficient	Variant			
	i	ii	iii	iv
$1 - \sigma'$	0.695 (33.25)	0.705 (17.66)	0.691 (33.35)	0.703 (17.65)
$\sigma' \log \alpha'_0$	1.636 (425.82)		1.859 (172.76)	
$\sigma' \log \alpha'_{AL}$		1.929 (235.51)		1.859 (195.90)
$\sigma' \log \alpha'_{CC}$		1.915 (237.26)		1.935 (180.98)
$\sigma' \log \alpha'_{LA}$		1.651 (137.17)		1.660 (108.16)
$\sigma' \log \alpha'_{RV}$		1.408 (210.81)		1.417 (121.81)
$\sigma' \log \alpha'_{SB}$		1.496 (227.95)		1.505 (131.22)
$\sigma' \log \alpha'_{SD}$		1.681 (210.81)		1.687 (156.41)
$-T$			-0.078 (22.10)	-0.003 (0.94)
R^2	0.136	0.557	0.191	0.557
F-test*		632.81		575.85

Note: d'_i is a dummy variable with a value of one if an observation is from county i , and zero otherwise.

*test of the hypothesis that: $\alpha'_i = \alpha'_j = \alpha'_0$

estate expenditures, not on the unit prices of housing services or real estate. The unobservability of unit prices has led to great uncertainty about the responsiveness of housing demand to variations in relative prices. The results reported in tables 2 and 3, however, permit the unit price of housing services to be computed from observations on factor prices. Thus, since price equals marginal cost,

$$(9) \quad P = [(\alpha')^{\sigma'} (jr)^{1-\sigma'} + e^{1-\sigma'}]^{1/(1-\sigma')}$$

where r , in turn, is computed from capital and land prices using equation (7).

In this section, we use this insight to estimate the parameters of the household demand curve for single detached housing.

We assume a log-linear demand curve (see deLeeuw, 1971) of the form:

$$(10) \quad \text{Log } \tilde{H} = \alpha_0 + \alpha_1 \log (Y/P_0) + \alpha_2 \log (P/P_0)$$

where $\tilde{H}$ is the capitalized flow of housing services, Y is household income and P_0 is the price of other (non-housing) goods. Household income is measured by "net effective income" as reported by the FHA. This figure, a transformation of gross household income to reflect "earning capacity (net of federal income tax) likely to prevail during the first third of the mortgage term," is only a crude measure of permanent income (see Muth, 1971, or Polinsky and Ellwood, 1979 for a discussion). The price of nonhousing housing goods is taken from the BLS consumer price index compiled annually by SMSA.

This empirical analysis is an extension of the work of Polinsky and Ellwood.

Polinsky and Ellwood regressed the sale price of newly-constructed dwellings upon household income and a price variable computed by inverting the production function for dwellings. In our terminology, they estimated household expenditures on the factor real estate (rR) as a function of income and real estate prices (r). Variation in real estate prices was derived from individual variation in land prices (λ) and metropolitan metropolitan-wide variation in capital costs (k).

In contrast, the results in equation 11 report household demands for the capitalized flow of housing services ($\tilde{H} = H/j$) as a function of income and the price of housing services (P); variation in housing prices is derived from individual variation in interest costs (j), land (λ), and real estate (r) prices, and metropolitan-wide variation in the prices of capital (k) and operating inputs (e).

The regression estimate of equation (10), based on a larger national sample of 7378 observations is:

$$(11) \quad \text{Log } \tilde{H} = 10.480 + 0.346 \log(Y/P_0) - 0.792 \log(P/P_0)$$

(59.36)

(38.93)

(63.79)

$R^2 = .412$

where t ratios are in parentheses.

The results are essentially the same when the output price of housing services is calculated according to any of several methods.⁴ The price elasticity of demand is estimated to be -0.79 with a 95 percent confidence interval from -0.77

⁴ In estimating equation (10), flows of housing services are computed from the production functions (equations 1a and 1b) directly. Alternative methods, for example computing housing services from the homogeneity condition and the pricing relationship (equations 3b and 9) or from equations 1b, 3a, and 7 yield virtually identical results. This is true using prices computed from any of the four sets of parameters in tables 2 and 3.

to -0.81. The estimated income elasticity is 0.35.

The price elasticity estimates compare rather closely with those of Polinsky and Ellwood (-0.67 ± 0.02), based upon a single cross section of FHA data, and with the less precise results reported by Hanushek and Quigley (1980, 1982) based upon longitudinal observations on renters generated in the Housing Allowance Demand Experiment in the Pittsburgh (-0.64 ± 0.30) and Phoenix (-0.45 ± 0.25) metropolitan areas. The income elasticity estimate reported by Polinsky and Ellwood is 0.38, based upon the same definition of income. Friedman and Weinberg (1981) report income elasticities of 0.25 (Phoenix) and 0.26 (Pittsburgh) based on data from the Housing Allowance Demand Experiment.

III. EXERCISING THE MODEL: "NATURAL" CONSERVATION

Knowledge of the parameters of production and demand, together with the assumptions already made about market conditions, is sufficient to estimate the market response to variations in energy prices.

Specifically, consider the implications of the production function, the demand curve, the homogeneity assumption, and the first order condition for profit maximization.

Production:

$$(12a) \quad H = [(692 d_{AL} + 659 d_{CC} + 224 d_{LA} + 118 d_{RV} + 159 d_{SB} + 298 d_{SD})(jR)^{-0.42} + E^{-0.42 - 0.39}]$$

Demand:

$$(12b) \quad H = 35.60(10)^3 (Y/P_0)^{0.35} (P/P_0)^{-0.79}$$

Homogeneity:

$$(12c) \quad P = (R/H)j \quad r + (E/H) \quad e$$

First Order Condition:

$$(12d) \quad (r/e) = (692d_{AL} + 659d_{CC} + 224d_{LA} + 118d_{RV} + 159d_{SB} + 298d_{SD}) (jR/E)^{-1.42}$$

The system consists of four equations (12a) through (12d) in unknowns H, R, E, and P. Given the level of income Y and prices e, r, λ , j, and P_0 , the model can be solved for the equilibrium quantities of housing, real estate, and energy and the output price of housing.

Table 4 indicates the solution to the model at various prices for residential energy. The top part of the table indicates the percentage change in housing prices as the price of energy inputs varies. The changes in housing prices are computed from the production function, the first order conditions and the homogeneity restriction. The second part of the table indicates the reductions in the quantity of housing consumed as a result of energy price increases. These changes are computed from the demand equation, given the output price changes. The third and fourth parts of the table indicate changes in the relative intensity of real estate and energy in housing output as energy prices increase. These changes are computed from the first order conditions.

As the table indicates, a tripling of energy prices is associated with a 34 percent increase in housing prices in Riverside County, a 22 percent increase in the price of housing services in Alameda County, and about a 27 percent rise in housing prices in Los Angeles. By way of comparison, if real estate could not be substituted for energy in production, then the data in Table 1 suggest that a tripling of energy prices would lead to housing price increases of 41 percent in Riverside County, 24 percent in Alameda and 33 percent in Los Angeles County.

Table 4
EFFECTS OF ENERGY PRICE CHANGES
ON THE CALIFORNIA HOUSING MARKET

Energy Price Index	Los Angeles (LA)	Alameda (AL)	Contra Costa (CC)	San Diego (SD)	San Bernardino (SB)	Riverside (RI)
Housing Prices						
100	100	100	100	100	100	100
110	102	101	101	102	102	102
125	104	103	103	104	104	105
150	108	106	106	107	109	109
200	115	111	112	114	117	118
300	127	122	122	127	131	134
Housing Consumption						
100	100	100	100	100	100	100
110	99	99	99	99	99	99
125	97	98	98	97	97	96
150	94	96	96	95	94	93
200	90	92	92	90	89	88
300	83	86	86	83	81	80
Real Estate Per Unit of Housing						
100	100	100	100	100	100	100
110	101	101	101	101	101	101
125	101	101	101	101	101	101
150	102	102	102	102	102	103
200	104	103	103	104	105	105
300	107	106	106	107	108	109
Energy Per Unit of Housing						
100	100	100	100	100	100	100
110	98	98	98	98	98	98
125	95	94	94	95	95	95
150	91	90	90	91	91	91
200	85	84	84	85	85	85
300	78	76	77	77	78	79

Source: Computed from equations (12a) through (12d)

The increased price of housing induces "conservation", on the part of consumers who reduce their consumption of housing services. In Riverside County, for example, a tripling of energy prices results in a 20 percent reduction in the consumption of housing services, in Alameda County, it translates into a 14 percent reduction in housing consumption.

Increases in energy prices also induce "conservation" in the building supply industry, as real estate is substituted for energy in the production of housing services. In Riverside County, a tripling of the price of energy is associated with a 9 percent increase in real estate inputs per unit of output, and a 21 percent reduction in energy inputs per unit of output. In Alameda County, real estate inputs increase by 6 percent and energy inputs decline by 24 percent, per unit of housing output.

Clearly higher energy prices induce a substantial conservation response among housing suppliers and final consumers, with some variation in energy savings, prices and housing consumption across counties. Gross reductions in the derived demand for residential energy from a tripling of energy prices amount to 37 percent in Riverside County and 35 percent in Alameda County.

IV. THE ECONOMIC EFFECT OF REGULATION

The California standards for new residential construction, adopted by the California Energy Commission in 1980, became effective on July 23, 1983. These standards were designed to meet statutory language specifying an economic crite-

⁵ According to the 1977 revision of the statutory language dealing with building efficiency, section 25402 of the California Public Resources Code states: "The [energy] standards shall be cost effective when taken in their entirety, and when amortized over the economic life of the building when compared with historic practice."

rion, namely cost-effectiveness, as an objective.⁵ These standards were developed with a heavy reliance upon "science." Meteorologists were influential in defining the regional character of the standards and in devising a set of distinct climate zones for their separate application. Engineers, physicists and simulation experts were influential in promulgating the performance features of the standards and in specifying the components of standards.

The criterion of cost-effectiveness permits a comparison of the conservation mandated by the standards-setting process with the level of conservation arising from market forces. In particular, the California Energy Commission itself has prepared estimates of the additional residential construction costs imposed by the standards in each of the climate zones of the State. These standards, prepared by assuming a compound real growth rate of energy costs of ten percent per year over the economic lives of properties, are estimated to add between \$499 (in San Diego County) and \$1,946 (in Contra Costa County) to the costs of construction.⁶

Table 5 compares the effects of the mandated standards with the "natural" conservation which would be observed in response to higher energy prices. Part A summarizes the mandated response to a ten percent compound increase in energy prices. The first row indicates for each county the increase in real estate input (rR) costs mandated by the standards as a percent of initial average real estate costs. The second row indicates the energy saved per unit of housing output (E/H) by these standards, measured as a percent of initial energy consumption. These estimates are computed from the production function. The im-

⁶ These estimates are described in California Energy Commission, Conservation Division, Briefing Package, New Residential Building Standards, Revised, April 1983.

Table 5
COMPARISON OF MANDATED ENERGY STANDARDS WITH
MARKET RESPONSES TO HIGHER ENERGY PRICES

	<u>Los Angeles (LA)</u>	<u>Alameda (AL)</u>	<u>Contra Costa (CC)</u>	<u>San Diego (SD)</u>	<u>San Bernardino (SB)</u>	<u>Riverside (RI)</u>
A) Mandated Response to Ten Percent Energy Price Increase.						
Additional Cost of Con- struction	1.03-	0.95-	1.40-	0.43-	1.87-	1.68-
Energy Saved Per Unit of Housing Service	13.67	12.58	17.58	5.87	11.33	11.74
Increase in Price of Housing Service	1.64	1.29	1.34	1.59	1.91	2.00
B) Market Response to Ten Percent Energy Price Increase.						
Additional Cost of Con- struction	0.47-	0.37-	0.37-	0.46-	0.53-	0.57-
Energy Saved Per Unit of Housing Service	2.34	2.43	2.43	2.35	2.28	2.24
Increase in Price of Housing Services	1.58	1.25	1.26	1.54	1.80	1.93
C) Loss from Standards, as Percent of Total Loss in Consumer Satisfaction from Regulation and From Energy Price Increase of:						
Ten Percent	2.66-	2.14-	4.02-	0.29-	1.85-	2.05-
Five Percent	62.52	60.00	69.61	50.42	58.41	59.37
Two Percent	84.81	83.83	87.71	79.91	83.14	83.52

Source: See text for sources and methodology.

sition of these standards does conserve energy. Energy consumption per unit of housing service is reduced by 6-18 percent. The third row indicates the increase in the unit price of housing services (P) resulting from the increase in energy prices and the mandated construction cost. These price increases are computed from the marginal cost function. Housing services increase in price by 1.6-2.5 percent.

Part B of the table indicates the market response to an equivalent increase in energy costs. The market response is an increase of only about a half percent in real estate inputs, and a savings of less energy per unit of housing output -- 2 to 4 percent, instead of the larger savings implied by the standards. When the economically efficient level of substitution is made, the price of housing services increase only by 1.3 to 1.9 percent.

With these higher prices, consumers are worse off under the mandatory standards than under the "natural" conservation regime. Part C of the table compares the well-being of consumers under the market outcome and that dictated by the standards. The first line of this part presents information on the losses suffered by housing consumers as a result of higher energy prices and the imposition of energy regulation. Given the log-linear form of the demand curve, equation (11), it can be shown (see Hauseman, 1981) that the compensating variation (Δ) for a change in housing prices from P^0 to P^1 is

$$(13) \quad \Delta_{01} = \left\{ \frac{1 - \epsilon_1}{(1 + \epsilon_2) y^{\epsilon_1}} [P^1 H^1 - P^0 H^0] + y^{1-\epsilon_1} \right\}^{1/(1-\epsilon_1)}$$

Increased energy prices cause housing prices to rise from P^0 to P^1 , and energy regulations cause housing prices to increase further from P^1 to P^2 . The

first line of panel C presents the additional loss to consumers caused by the regulations, as a fraction of the losses caused by higher energy prices (i.e., ${}_1\Delta_2/{}_0\Delta_1$). These computations are presented for a 10 percent compound increase in energy prices (the economic assumption underlying the energy regulation) at the mean income in each county.

The results indicate that the standards impose an additional loss of 0.3 to 4.0 percent, when compared with higher energy prices. It therefore appears, that the losses caused by the standards per se are quite small. Stated another way, if for some reason energy is priced in the market below its scarcity value to society, the mispricing need not be large at all to justify the restrictions on consumer sovereignty imposed by the regulation. In fact, if a dollar's worth of energy is worth \$1.03 to society, the standards seem to be completely justified.

However, before concluding that these standards are preferred to the market outcome, the reader should consult the last two lines of the table. Recent experience would suggest that a ten percent compound growth in real energy prices is too large -- perhaps by a multiple of three or four. If the course of energy price increase is lower, the losses from the standards may be quite substantial. Indeed, consumer losses from the regulations may be four or five times as large as the losses resulting from higher energy prices.

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