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ESTIMATION OF THE PRICE ELASTICITY OF DEMAND
FACING METROPOLITAN PRODUCERS*

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Metropolitan governments are continually faced with the problem of choosing a mix of taxes. Taxes can be applied to capital, labor, or output, and these can often be restricted to individual sectors. The ideal program, from a purely metropolitan point of view, and assuming it is a unilateral action, would be to tax the sector or factor which is able to shift the burden entirely to economic agents outside the area. The ability of an industry to shift the tax, whether levied on factors or output, depends largely[1] on the elasticity of demand for its output from non-metropolitan consumers and the share of its output which is exported. If the export demand curve is perfectly elastic, then no taxes can be shifted forward onto external consumers, and the tax will be borne by the factors, primarily capital. This tax thus leads to capital flight. However, if it is perfectly inelastic, then the burden can be almost completely shifted

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[1] If the tax is not shifted forward, it will be shifted backward onto the factors of production. The extent of this backward shift depends upon the elasticity of supply of the factors to an industry which presumably would be quite large in a metropolitan labor market, especially recognizing the important role of labor migration into a region in response to favorable employment opportunities. The elasticity of supply of capital is also presumably very large, since this is also a national market. See Engle [4]. If the tax is shifted onto capital, it is likely to leave the metropolitan area.

out of the metropolitan area. The price elasticity of demand for metropolitan exports is the single most important parameter in deciding which sector to tax.

Another closely related function undertaken by metropolitan governments is economic development. This takes a variety of forms which can mostly be seen as subsidizing new firms to encourage them to locate in the area. Like taxes, but in the opposite directions, the effects of a subsidy will depend substantially upon the price elasticity of demand. If the demand function is inelastic, the subsidy will have little effect on output and may decrease price.

A variety of other policy decisions must be made based upon this parameter. The differentially rising costs of energy between regions can be viewed as an upward shift in the supply schedule for output in the high cost cities. The effect on the output of these cities will be determined by the price elasticities of demand.

Low labor costs are generally given credit for the rapid economic development of the Southeast. Rising labor costs in any metropolitan area must be a major influence on shifting the supply of output schedule. The effect on output of such a rise in wages, will depend upon the demand function. Similarly, an upgrading of the skill or education characteristics of a labor force will be seen as lowering the supply function. The benefits of any job training program will depend in part on the price elasticity of demand.

The benefits from improvements in the transportation system will also hinge upon these elasticities. Only if there is a substantial price elasticity will a small decrease in transport costs lead to much of an increase in output.

In summary, the level of factor costs is very critical in highly competitive industries. Any increase will lead to a substantial decrease in output and eventual capital outmigration. However, in industries with more of a monopolistic position, factor cost increases can be passed on to consumers and if it is an export industry, these will be external consumers.

In this paper, price elasticities of demand for manufacturing industries are estimated using time series data for the Boston metropolitan area. This is part of a larger enterprise for the area which is described in [3], [4], [5], [6] and a companion study of residential location within the area [1].

Section I of this paper derives an estimable relation for the demand price elasticity. Sections II and III discuss a variety of estimation and data problems, respectively. In Sections IV and V, the empirical results are presented, and in Section VI, the policy implications are discussed.

I. Derivation of a Simple Model

In order to estimate the price elasticity of demand, it is necessary to disentangle supply and demand effects. In this section, industry supply and demand functions are specified and used to derive estimable relationships.

First, the appropriate measure of quantity must be specified. The natural measure of quantity from the supply point of view is value added in the sector. However, from a demand point of view, the most common unit would be final product. Unfortunately, this measure is inconvenient, since the demand for final products sold in a city does not give much information as to the source of the factor inputs. The goods may have been produced there, or may have been produced entirely in some other location. The difference in terms of job creation is enormous. Furthermore, demand for the output of some sectors would not be final demand but rather intermediate demand from another firm. The assumption which is made is that value added by a particular sector can be treated like a product which has a price and a demand curve. At each stage of the production process, firms will seek inputs at lowest cost and thus will choose either to buy them locally or to import them.

The demand for the value added from a local industry is the key structural relation to be estimated. As the local price of products rises, the quantity demanded will decrease. This decrease will occur partly because consumers of this good will shift to some other products through the conventional income and substitution effects. However, the major effect should be through the shift to the same good which is produced in another region. For products which can be easily transported and for which there are many alternative sources of supply, the price elasticity of demand should be very large and negative, primarily because of this regional substitution effect.

A simple specification for the demand function for metropolitan output is,

$$q = b_o + b_1 y^* + b_2 (p^* - p) \tag{1}$$

where q is the logarithm of value added in constant dollars, p is the log of the price of goods produced in the city, and p* is the log of the price of this good in the national market multiplied by the percent of value which is net of transportation costs to the national market. The variable y* is the log of an income measure for the consumers of this good. In order to avoid estimating income elasticities for all goods, the total constant dollar output in the nation is taken as the measure of the size of the market. According to this specification, b_1 is the elasticity of metropolitan production relative to industry output, and b_2 is the price elasticity of demand for goods from this city. Notice that the demand function is homogenous with respect to prices and that if price elasticities are zero, a "pure demand" model is obtained. If, on the other extreme, b_2 approaches infinity, the model becomes the competitive model whereby local prices must be equal to national prices net of transport costs.

A supply function for output can be derived from a production function. For simplicity and because of its long history, the Cobb-Douglas production function is chosen for a first approximation. The more realistic CES form leads to more complicated but similar results. Although the applicability of this form has been questioned, the evidence [11] frequently supports it. Let

$$q = a_o + a_1 k + a_2 \ell \qquad (2)$$

where k and ℓ are the logs of capital stock and employment. While it is reasonable in the short run to take the level of capital stock as fixed since investment plans take several years, it is not plausible to treat employment as fixed in the short run. Presumably firms hire more labor in good times and when the price of labor is low. The demand for labor is a derived demand for a variable factor of production. Assuming there are many firms in each industry, they will act like perfect competitors in both the factor and the product markets. Thus the derived demand for labor will be obtained by setting the marginal value product equal to the wage rate.

$$\ell = q - (w - p) + \log (a_2) \tag{3}$$

where w is the log of the wage rate specific to the industry in question. The wage it will depend upon the skill requirements of the labor force demanded by the firm and upon the wages of each type of worker. The variable w might also include the costs of other variable factors of production which are used in fixed proportion with labor. One example might be energy.

Unfortunately ,equations (1), (2), and (3) cannot be estimated using standard simultaneous equation techniques because some of the required variables are unobservables. There is no data on the price of output from local firms. Furthermore, the value added data is in current dollars and is only available for scattered years since 1950. The observables are ℓ, k, w, y* and p*. Solving for ℓ in terms of the other four variables yields the reduced form equation:

$$\ell = \frac{a_1(b_2-1)}{\Delta} k + \frac{b_1}{\Delta} y^* - \frac{b_2}{\Delta} (w - p^*) + c_o \tag{4}$$

where $\Delta = a_2 + b_2 - a_2b_2$ and c_o is a constant term.

Equation (4) is the main estimating equation for all sectors of the model. In the empirical section, it is expanded to include additional variables, to allow distributed lags and to impose additional constraints. However, the basic equation remains unchanged and it merits careful attention in order to understand some of its features.

Since a_1 and a_2 must be between zero and one, the denominator will always be positive. Thus an increase in national demand will unambiguously increase employment while an increase in local wages (or a decrease in national prices) will decrease employment. However, an increase in capacity can have either effect. If the price elasticity of demand is small, an increase in the capital stock will displace workers, while if it is larger than one, an increase in the capital stock will increase employment and output and slightly decrease price.

The specific effects of wage changes must also be qualified. If the wage rate rises, employment will fall but total payroll may either rise or fall. Since the coefficient of the real wage can be shown to be less than minus one if and only if b_2 is greater than one, the demand elasticity is again the crucial parameter. If b_2 is less than one, the surprising result is that an increase in wages will actually increase payroll and consequently incomes. To understand this result, recall that although individual firms behave as perfect competitors, the industry faces a steeply downward sloping demand curve. As a result, any form of collusion between firms will enable them to extract the monopoly profits. A rise in wages is a signal for all firms to restrict output and thus all will increase profits and payroll.

These policy multipliers suggest that the elasticity of demand is a crucial parameter in evaluating local policies. If demand is inelastic, the government should consider taxing the sector to reap the monopoly profits, while if demand is elastic, the preferred policy may be to subsidize new investment. Throughout the empirical work, the elasticity of demand for each sector will be the parameter of paramount interest.

Within the context of this model, it is possible to test several important hypotheses. A "pure" demand model assumes that prices do not matter, and that output is only a function of demand. This hypothesis is merely the hypothesis that $b_2 = 0$. A simple test of this hypothesis is a test of whether real wages are significantly different from zero in equation (4). In this case, capital should be negative, since capital and labor are substitutes.

An alternative extreme model is a "pure" supply model. In this case, the limit to output is the ability of a region to supply the product. At a particular world price, any amount can be sold, but because of finite resources, only a limited amount is produced. This model is the basic small country model studied so intensively in international trade theory where the world market is assumed to be so much bigger than any individual country that price elasticities are infinite. A testable hypothesis is that b_2 is infinite. In equation (4) this can easily be evaluated by testing the hypothesis that y* has a zero coefficient. Again, if further restrictions are imposed, additional tests can be undertaken. For example, if constant returns to scale are assumed then the coefficient of k must also be one.

II. Estimation Procedures

There are a variety of issues involved with the estimation of the structural parameters of this system. First, it is apparent that equation (4) is a reduced form derived from the three structural relations (1), (2), and (3). Although in principle there are two other reduced forms for the dependent variables p and q, these cannot be estimated because the dependent variables are unobservable. As usual with reduced forms, the coefficients are the policy multipliers. If, however, the structural parameters are of particular interest, the identificaton of these parameters must be investigated. From a quick examination of (4), it can be seen that there are six structural parameters but only four reduced form coefficients. Consequently, these parameters are clearly unidentified. Even, admitting that b_o and a_o are unidentified, it is not possible to solve for the four remaining in terms of the three reduced form regression coefficients.

To identify these parameters, a priori restrictions are necessary. Two possibilities are immediately available. First, the scattered data on value added by sector in Boston can be used to obtain an estimate of labor's share, $\hat{a}_2$. Second, the assumption of constant returns to scale will provide another restriction. Either of these restrictions will exactly identify the remaining structural parameters; both of them together will over-identify the system. When both are employed, it is possible to test the over-identifying restriction. It is also possible to impose this restriction upon the reduced form so that a unique structural estimate is implied. In this case, equation (4) is replaced by

$$(5) \qquad \ell + w - p^* = \frac{a_1(b_2-1)}{\Delta}\left(k - \frac{\hat{a}_2}{1-\hat{a}_2}(w-p^*)\right) + \frac{b_1}{\Delta} y^* + c_o .$$

Notice that the coefficient of k is the same in both the restricted and the unrestricted reduced form, and that it can have either sign depending on whether b_2 is greater or less than one. The dependent variable now is payroll divided by the US price level. This form is the estimating equation which will be used for most of the results.

A second important problem is the treatment of serial correlation. Durbin-Watson statistics for the least squares versions of equations (4) and (5) are invariably low. This is not surprising since the model is very simple relative to the complexities of a metropolitan economy; there may be omitted variables. To obtain point estimates of the equations, it might be possible to ignore the serial correlation since least squares is still unbiased even if inefficient. However, to do hypothesis testing, it is necessary to also have at least consistent estimates of the standard errors and therefore a serial correlation correction must be made. Furthermore, the structural coefficients are non-linear functions of the reduced form coefficients and therefore the estimates will only have asymptotic properties even if least squares is used for the reduced forms.

Four different procedures were used to correct for serial correlation. Two methods (AUTO 1 and AUTO 2) assume a first and second order Markov process respectively, and solve the full likelihood equations non-linearly including the initial value correction which is very important for small samples [8]. Assuming a first order model, a grid search suggested by Hildreth and Lu [9] (HILU) also yielded a solution to the likelihood equations, this time dropping the initial observation. Finally, in order to avoid making restrictive assumptions about the structure of the error process, a generalized least squares estimator based upon the spectrum of the disturbance was used

(SPECT). Monte Carlo tests of this estimator indicate quite satisfactory performance for small samples [7].

III. Data

To model Boston's economic situation, the manufacturing sector was disaggregated into four industries: two non-durable and two durable industries.[1] Non-durables one (ND1) consists of the textile, apparel and leather industries. This used to be a major sector of the Boston economy but since the second world war has been sharply declining in employment. In 1970 there were 34 thousand employees. Non-durables two (ND2) is the balance of the non-durable sector which in Boston is primarily food processing and printing and publishing. This sector has experienced a slow but steady decline over the sample period. Its 1970 employment was 77 thousand.

Durables one (D1) is the high technology sector consisting of electrical and non-electrical machinery, instruments and transportation equipment. Employment in this sector has moved erratically since 1950, reaching a peak in 1967 and a level of 123 thousand in 1970. Durables two (D2) is the balance of the durable processors and includes primary and fabricated metal products, stone clay and glass and other heavy industry. This sector has also varied over the period with a peak in 1953 and a very gradual decline since. The 1970 employment was 34 thousand.

The employment figures are annual average employment as collected by the Massachusetts Division of Employment Security for the 1970 definition of the SMSA. Minor changes were made at the two digit SIC level to adjust

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[1] The SIC codes are: ND1: 22, 23, 31, ND2: 20, 26, 27, 28, 29, 30, D1: 35, 36, 37, 38, D2: 24, 25, 32, 33, 34, 39

for 1958 definition changes. Prices are weighted averages of wholesale price indices as constructed for the output of two digit sectors by Eckstein and Wyss [2] and aggregated to the four categories for this study. Total value added in the sector in the US was taken from various issues of the Annual Surveys and Censuses of Manufacturers. Transport costs were constructed from actual annual trucking rates and data from the Censuses of Transportation to get a time series of the percent of value which was transport cost.

The most critical and difficult data series were the capital stock series. Because three of the four sectors were declining in employment it was essential to correct for depreciation and vintage. The simple approach used was to approximate the benchmark values for gross book value by assuming a sudden death type of depreciation or scrapping. Since the gross book value is the value of the stock not yet scrapped measured in the original prices, it should be approximately equal to the sum of investment in current dollars over the past n years where n is the average lifetime before equipment is scrapped or sold. The state benchmark was taken from the 1958 Census of Manufacturers and an SMSA value was estimated assuming a constant capital-output ratio. Annual investment since 1954 was obtained again from the Annual Surveys. From 1929 to 1953, it was imputed as a variable fraction of US manufacturing investment including resale of government capital after World War II, as compiled by the Commerce Department [12]. The fraction was linearly interpolated from observations in 1929, 1937 and 1947 of the profit of each Boston sector relative to the total manufacturing profits in the nation. From these investment series a lifetime between 15 and 21 years was found for each sector and by deflating by a national investment deflator and cumulating, capital stock series for each sector were obtained. A two year average of this series was used in the regressions to pick up the time before investment comes "on line."

These capital stock series show ND1 rapidly falling while D1 is rapidly increasing. ND2 is slowly increasing and D2 is stationary. The capital-labor ratio in 1970 is lowest for ND1 and highest for ND2 and D2, which presumably require a great amount of capital per worker for heavy manufacturing and assembly line type food processing.

Although great care was taken in constructing these series, it is clear that there are many untestable assumptions implicit in the procedure. Insofar as the econometric results are sensitive to variations in the methodology used, the results must be considered as tentative.

IV. Results for the Basic Model

Equations (4) and (5) were estimated for the four manufacturing sectors with annual Boston data from 1950 to 1971. These equations were estimated assuming a first order Markov error process, adjusting the first observation, and solving the non-linear likelihood equations. The estimates are presented in Table I.

The overall fits are rather good with standard errors between 2 and 8%. The signs are generally appropriate and most of the coefficients have large t-statistics. Notice first the coefficient of k in both the unrestricted and the restricted form. This coefficient will be positive if the price elasticity of demand is greater than one and negative otherwise. Thus, only one sector appears to face a demand function with price elasticity greater than one. The plausibility of this rather surprising result will be discussed shortly.

TABLE 1

Regression Coefficients for Simplest Model+

VARIABLE	ND1		ND2		D1		D2	
Dependent	ℓ	$\ell+w-p^*$	ℓ	$\ell+w-p^*$	ℓ	$\ell+w-p^*$	ℓ	$\ell+w-p^*$
k	.310 (.074) (4.14)		-.466 (.352) (-1.32)		-.552 (.738) (-.748)		-.059 (.189) (-.310)	
$k-\frac{\hat{a}_2}{1-\hat{a}_2}(w-p^*)$		.165 (.067) (2.46)		-.322 (.111) (-2.89)		-.306 (.766) (-.400)		-.198 (.100) (-1.98)
w-p*	-.813 (.200) (-4.05)		-.557 (.170) (-3.28)		.305 (1.03) (.296)		-.743 (.119) (-6.23)	
y*	.589 (.210) (2.80)	.669 (.215) (3.11)	.269 (.127) (2.11)	.232 (.094) (2.48)	.523 (.185) (2.82)	.779 (.122) (6.40)	.298 (.086) (3.46)	.312 (.083) (3.76)
Constant	2.02	4.40	12.61	12.39	-.470	-.260	10.00	10.77
$\hat{\rho}$	.78	.90	.46	.46	.77	.79	.70	.72
Standard Error of Regression	.035	.039	.020	.020	.069	.073	.025	.025
D.W.	1.14	1.67	1.60	1.61	1.58	1.86	1.71	1.76

+Standard errors and t-statistics are below coefficients. All equations are estimated with a first order error model (AUTO1).

The wage term must always be negative and it is negative and very significant in three sectors. There is, however, a further condition on the size of the wage coefficient in the unrestricted reduced form. If the price elasticity is greater than one, the coefficient of wages must be less than minus one. In ND1 this is violated though not significantly (the t-statistic for this test is .9). The income term should always be positive and in fact it is positive and significant in all six regressions.

Because of the two (both insignificant) anomalies in the wage coefficient in the unrestricted reduced form, the structural coefficients cannot be recovered by making just one of the two a priori assumptions. The restricted reduced form which assumes both constant returns to scale and a known labor share, is therefore more attractive, especially in view of the collinearity between the independent regressors which makes estimation of individual coefficients difficult.

To test the overidentifying restriction, two tests were used: a likelihood ratio test statistic which is asymptotically distributed as chi square with one degree of freedom, and an F-statistic which is only asymptotically (because of serial correlation) distributed as F. Fortunately, it was not possible to reject the a priori information at the 1% level for either of the tests for any of the sectors. At the 5% level, ND1 did fail both tests, but all others easily passed. However, recalling that ND1 did not satisfy other more basic restrictions on the unrestricted reduced form, which must be taken as part of the specification of the alternative to the null hypothesis, it is clear that the sum of squared residuals for that sector is too small in the unrestricted case and that the tests were biased toward rejection. Correction for this could easily lead to acceptance of the overidentifying restrictions.

Estimates of the structural parameters and their asymptotic standard errors can simply be found from the restricted estimates and the variance covariance matrix. The parameters corresponding to these sectors are given in Table II. The first line is derived from the estimates of Table I and the second line is from the spectral estimates given in Tables III-VI.[1]

TABLE II

Structural Coefficients and Asymptotic Standard Errors

	ND1		ND2		D1		D2	
	b_1	b_2	b_1	b_2	b_1	b_2	b_1	b_2
AUTO1	.801	1.472	.176	.406	.597	.479	.260	.648
	(.310)	(.230)	(.085)	(.156)	(.345)	(1.00)	(.085)	(.148)
SPECT	1.89	2.15	.142	.367	.711	.567	.367	.761
	(.851)	(.480)	(.054)	(.106)	(.400)	(1.06)	(.112)	(.155)

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[1]The tests of the overidentifying restrictions came out exactly the same for the spectral estimators as for the AUTO1 estimates.

Do these results suggest that Boston's manufacturing sectors are primarily demand or supply oriented? As argued previously, a pure supply model would find that b_2 was infinite and that the coefficient of income (in either restricted or unrestricted form) would be zero. This hypothesis is rejected in every case so demand must have an influence. On the other hand, the pure demand model can be tested by examining the hypothesis that the price elasticity, b_2, is equal to zero. For three of the sectors, this is rejected easily, while for durables one, the high technology sector, it is not. Looking at the unrestricted estimates, the hypothesis that $b_2=0$ means that the real wage does not enter the regression. Again, this is rejected in all but D1. Thus three of the four sectors appear to be a synthesis of demand and supply effects, while the fourth, D1, behaves like a pure demand sector.

It is interesting that only ND1 shows a price elasticity greater than one, and even this is not as large as one might expect. How plausible is this result? First, even in empirical studies of international trading patterns, the price elasticities of small countries are not very large [9], so it may not be surprising that several of these are less than one. Second, data from the 63 and 67 Census of Transportation corroborate the result. Other things being equal, industries which ship goods to a large market area might expect to have more competitors. Also, goods which are relatively inexpensive to ship are likely to find more competition from distant regional producers. For the four sectors the percent of output shipped less than 100 miles was: ND1-25%, ND2-44%, D1-17% and D2-30%. Similarly, transport cost as a percent of value was: ND1 -- less than 1%, ND2 -- 10%, D1 -- less than 1%, D2 -- 7%. In both cases, with the exception of D1, the sector which expects more competition has a higher price elasticity. The exception is, however, not surprising. The growth of the high technology sector in Boston was largely driven by government defense and aerospace contracts for which costs may be a smaller consideration than in the private market. Furthermore, because of the technological resources in the Boston academic community, it is not surprising that the sector exhibits a degree of monopoly power. In conclusion, not only the size but the rankings seem consistent with other information.

V. Further Results

The model presented in the preceding section is rather simple, both in theory and in estimation. Potentially a variety of improvements could be made, at least for specific industries. In this section, several additional estimates of versions of equation (5) are presented. The issues to be addressed are:

a) Would other forms of serial correlation be better?

b) Are the results affected by excess capacity?

c) Is there a lag structure?

d) Do non-exported shipments behave differently?

e) Is productivity important?

In tables III to VI estimates designed to answer these questions are tabulated.

The first comparison between SPECT, OLS and AUTO1 suggests that the differences in estimation technique do change the parameters somewhat but that qualitative differences do not occur, except in D1 where capital switches

TABLE III

ND1

Variable METHOD	SPECT	OLS	OLS/EXCL 54, 58, 70	HILU	HILU	HILU	HILU
$k-\frac{\hat{a}_2}{1-\hat{a}_2}(w-p^*)$	.238 (.069) (3.43)	.325 (.092) (3.53)	.404 (.099) (4.08)	.091 (.051) (1.78)	.157 (.078 (2.01)	.155 (.086) (1.79)	.182 (.096) (1.91)
y^*	.878 (.297) (2.96)	1.28 (.402) (3.18)	1.67 (.433) (3.85)	.498 (0.178) (2.80)	.405 (.228) (1.77)	.777 (.240) (3.24)	.815 (.312) (2.61)
ℓ_{t-1}				.434 (.152) (2.86)			
y^*_{t-1}					-.090 (.187) (-.48)		
y^d_{Bos}						-.456 (.407) (-.112)	
tp							-.287 (.526) (-.545)
Const	-.032	-8.86	-17.67	3.33	12.72	10.12	5.58
$\hat{\rho}$				.50	.55	.75	.70
SER	.050	.052	.048	.025	.03	.039	.040
Durbin-Watson	1.42	.87	1.19	1.94	.81	1.43	1.74

TABLE IV

ND2

VARIABLE \ METHOD	SPECT	OLS	OLS OMIT 54, 58, 70	HILU	HILU	HILU	HILU
$k-\frac{\hat{a}_2}{1-\hat{a}_2}(w-p^*)$	-.351 (.080) (4.41)	-.292 (.114) (-2.56)	-.296 .113 (-2.62)	-.399 (.112) (-3.56)	-.235 (.136) (-1.72)	-.395 (.103) (-3.85)	-.435 (.113) (-3.86)
y^*	.191 (.062) (3.10)	.257 (.096) (2.69)	.255 (.094) (2.70)	.267 (.090) (2.95)	.495 (.147) (3.37)	.409 (.194) (2.11)	.837 (.299) (2.80)
ℓ_{t-1}				.674 (.228) (2.96)			
y^*_{t-1}					-.216 (.109) (-1.98)		
y^d_{Bos}						.224 (.234) (.953)	
p							-.424 (.352) (-1.20)
Const	13.23	11.96	11.98	3.40	11.74	3.15	3.31
ρ				-.05	.40	.95	.95
SER	.030	.022	.021	.016	.016	.019	.019
Durbin-Watson	2.55	1.10	1.08	2.23	1.45	1.36	1.36

TABLE V

D1

VARIABLE \ METHOD	SPECT	OLS	OLS OMIT 54,58,70	HILU	HILU	HILU	HILU
$k - \frac{\hat{a}_2}{1-\hat{a}_2}(w-p^*)$	-.242 (.735) (-.33)	.811 (.635) (1.28)	.705 (.689) (1.02)	-.777 (.626) (-1.24)	-.528 (.620) (.851)	-.653 (.459) (-1.42)	-.530 (.386) (-1.37)
y^*	.883 (.080) (11.07)	.828 (.059) (13.98)	.839 (.066) (12.78)	.385 (.148) (2.59	.394 .142 (2.77)	.081 (.154) (5.21)	.834 (.115 (7.27)
ℓ_{t-1}				.200 (.184) (1.09)			
y^*_{t-1}					.127 (.144) (.879)		
y^d_{Bos}						1.21 (.271) (4.48)	
tp							-1.37 (.197) (-6.94)
Const	-2.52	3.34	2.62	5.39	5.35	-6.37	20.62
ρ				.90	.85	.35	.95
SER	.086	.088	.092	.054	.055	.046	.034
Durbin-Watson	1.35	.87	.91	1.78	1.51	.97	1.52

TABLE VI

D2

VARIABLE / METHOD	SPECT	OLS	OLS OMIT 54, 58, 70	HILU	HILU	HILU	HILU
$k-\frac{a_2}{1-a_2}(w-p^*)$	-.126 (.093) (-1.36)	-.017 (.089) (-.196)	-.061 (.097) (-.627)	-.161 (.113) (-1.42)	-.023 (.127) (-.183)	-.266 (.139) (1.92)	-.416 (.153) (-2.73)
y^*	.414 (.095) (4.37)	.551 (.096) (5.72)	.506 (.110) (4.60)	.452 (.092) (4.90)	.405 (.082) (4.97)	.204 (.094) (2.17)	.520 (.139) (3.73)
ℓ_{t-1}				.306 .185 (1.65)			
y^*_{t-1}					.142 (.073) (1.94)		
y^d_{Bos}						.603 (.280) (2.15)	
tp							-.403 (.257) (-1.57)
Const	8.56	5.63	6.56	4.24	5.70	1.84	11.22
ρ				.65	.70	.95	.70
Standard Error Regression	.029	.031	.030	.023	.023	.025	.024
Durbin-Watson	1.49	1.20	1.02	1.55	1.31	1.75	1.45

from positive insignificant to negative insignificant. Other unreported results using HILU and AUTO2 bear out this result.

In recession years it is unlikely that the capital stock is fully in use. Therefore, these observations may only be observations on the demand side and thus do not satisfy the reduced form relation. To test this, the three recession years 1954, 1958 and 1970 were excluded from the sample period. The results changed very little, especially considering that frequently these were years with large residuals. Other regressions run only using data from the '60's were also quite similar.

To test for a distributed lag structure, lagged values of independent and dependent variables were tried in both restricted and unrestricted forms. Generally the lagged cost variables were insignificant as were the lagged income variables. The latter are reported as well as the lagged dependent variables, in both cases estimated under the assumption of a first order error process. Only in D2 does the lagged income variable enter (almost) significantly with a reasonable sign. The lagged dependent variable is significant in two of the industries and of appropriate sign in all four. In all cases the implied lag structure is rather short with mean lags varying from 2 years to one quarter, and one might question the longest on the grounds of the estimated serial correlation coefficient.

Because a portion of the goods produced by each sector is sold directly to Boston residents, it is reasonable to suppose that the demand function may also depend upon Boston disposable income. This specification would allow the share exported to depend upon relative demands and the price level. It might also capture the intermediate good demand since Boston disposable income is closely related to Boston total value added. This variable comes in positively in three sectors and is significant in the two durable sectors. This lends credibility to the intermediate good argument, although the coefficients seem somewhat too large. A possible explanation here might be simultaneous equation bias. Generally the value added by one sector is a very small fraction of the Boston total. In 1970 the four manufacturing sectors produced value added which was ND1-3%, ND2-12%, D1-17%, D2-4% of Boston personal income. If there is bias, it should be most severe in D1.

While rising labor costs are impediments to production, they may be balanced by productivity increases. If productivity increases at the same rate everywhere in the nation, the real output per worker in the nation should be a reasonable and exogenous measure. The log of this variable, called tp for technical progress, was introduced into the regressions. It should have the same sign as the capital coefficient since productivity increases will increase employment only if the industry faces an elastic demand curve. Three of the four are of the right sign and in D1 it is highly significant. The result suggests that productivity increase in this sector has been an important explanation for the slow growth of employment in the face of rising capital stock and national demand.

In conclusion, the estimates of the restricted reduced form can be improved slightly for specific industries by incorporating distributed lags, Boston income, or productivity, but none of these changes alters the qualitative conclusions about the price elasticity of demand in the four sectors.

VI. Policy Implications

The policy implications of these empirical results are in some respects counter-intuitive and must be explicitly considered in both the short and the long run. Here only the effects on one industry will be analyzed. For an analysis of metropolitan changes through income and factor market linkages, see Engle [5].

The major empirical finding is that for the four manufacturing sectors in Boston, three face demand curves with price elasticities less than one. Only ND1, the declining sector of textiles, apparel and leather faces an elastic demand curve. The implication of this result for tax policy is clear. If one must unilaterally tax a sector, it should be one which faces an inelastic demand curve and therefore, taxes should be levied on D1, D2 and ND2 in preference to ND1. Taxes on these sectors will be shifted forward to consumers, most of whom are external to the metropolis, rather than backward to the factors of production. A backward shift would lead to lower returns to capital, subsequent capital outmigration and a commensurate decline in jobs.

In the same fashion, the sector which should be subsidized, if any, is ND1. Only in this industry will new investment lead to increases in employment, payroll, income and output. Only in this industry would the benefits from an investment subsidy be positive; of course, they may still not exceed the costs.

To make clear why there are no benefits from investments in other sectors, consider the impact of a government run firm. If this firm were established in the electronic, publishing, or food industries, it would find itself in direct competition with other firms in the metropolitan area. Contracts received by the government firm would be the same contracts lost by the private firms. The new jobs created by the government firm would be mirrored by decreases in the private firms who could not compete with the subsidized government company. The net effect on employment might even be negative, since the new capital might displace workers.

On the other hand, if this government firm produced textile products, its competition would be primarily textile firms in the Southeast. Therefore, the job increases would be at the expense of firms outside the metropolitan area.

In particular cases there may be qualifications to these implications. Throughout, it has been assumed that the demand by the rest of the world is unchanged by any particular policy action. If this is not the case, then a variety of alternative outcomes might be anticipated. For example, if a tax is not levied unilaterally, then the demand curve will move as well as the supply curve. A universally applied tax on textiles would not have the disasterous effect that a unilaterally applied tax has.

Frequently, a regional economic development commission will consider attracting a large firm which might locate elsewhere if it does not come to the region. In this case, this competitor will exist for the local firms regardless of the outcome of the moving firm's final decision; and therefore, the metropolitan area will lose fewer jobs if it can attract the new firm. Again, the demand curve shifts as well as the supply curve.[1]

Finally, a firm which produces a very specialized product may alter the demand for the industry if it produces in the city. In this case, the firm brings its own demand, rather than merely operating under

[1] This case was first pointed out to me by Greg Ingram.

the city demand curve. Each of these cases may be important in specific instances, but the general tendencies are probably more like the fixed demand model.

The model estimated in this paper can be used to analyze a variety of policies other than taxes and subsidies for specific industries. Rising variable costs of production in one city relative to other producers will have differential effects on different industries. The rapid relative rise of the cost of energy in New England should have only minor effects on the electronics industry which faces an inelastic demand curve, but a very detrimental effect on the textile industry which faces more competition. This is exacerbated by much larger energy input requirements for the textile sector. Similarly, the rising cost of labor will lead to substantial decreases in employment and output in the textile industry, but not in the electronics industry. Finally, decreases in transport costs will have their most substantial benefits on competitive industries such as the textile industry.

These results hold in the short run, when the capital stock cannot be changed. However, in the long run, capital is presumably elastically supplied depending on the marginal rate of return relative to some alternative. The extreme alternative to the short run analysis of the previous paragraphs is the assumption that capital is perfectly elastically supplied at an exogenously given price. In this case, both factor prices are exogenous and there is an output price at which an infinite amount could be produced; that is, the supply curve is horizontal. Price is therefore determined entirely by factor costs and output is just a function of the location of the demand schedule at this price.

Letting r^* be the logarithm of the opportunity cost of capital, entrepreneurs will invest until the marginal product of capital is equal to r^*.[1]

For the Cobb-Douglas production function this condition becomes

(6) $$r^* = \log(a_1) + q - k$$

Solving (1), (2), (3) and (6) for employment, assuming constant returns to scale the new reduced form is:

(7) $$\ell = \frac{-a_1(b_2-1)}{a_2} r^* - b_2(w-p^*) + b_1 y^* + c_o.$$

In the long run the policy multipliers are similar in direction but different in size. An increase in wages will again decrease employment but will possibly increase payroll, output and income depending on whether the price elasticity is less than one. Increased profits in the short run generate new investment which drives the profit rate back to the opportunity cost of capital again, leaving the level of profits, the level of the capital stock, and employment slightly higher.

Investment encouraged by the government at the margin will have no effect since the private market will merely make up the difference between this and the equilibrium level of capital stock. The government can however

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[1]This will be the marginal physical product assuming that the price of the investment goods is unchanged by policy.

subsidize or tax the entire capital stock, thereby changing the equilibrium quantities and income levels. Here it is again reasonable to subsidize (lower r*) those sectors which face elastic demand curves and tax those facing inelastic demand.

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