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SIMULATING THE EFFICIENCIES OF ALTERNATIVE INDUSTRY LOCATION SUBSIDIES IN KOREA

by

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The views presented herein are those of the author(s), and they should not be interpreted as reflecting those of the World Bank.

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Abstract

The Korean government, like many others in less developed countries, uses numerous carrots and sticks to influence the location choices of manufacturing firms. We develop an analytical model for comparing the economic efficiencies of alternative subsidy schemes, allowing for both input price subsidies and subsidies through public infrastructure investment.

To implement the model we estimate restricted translog cost functions for nine Korean manufacturing industries. Simulations based on these econometric estimates and others drawn from the literature enable us to compare loan guarantee plans, land price subsidies, wage bill subsidies, and infrastructure delivery schemes.

We find that the credit rationing policies of the Korean government (macro policies not set with industrial location in mind), make the most common and most popular location subsidy mechanism, loan guarantees, the most efficient as well. However, we further find that if the Korean government alters its credit rationing policies, location subsidy plans that lower the price of capital to firms (as the guarantees do) would become the least efficient mechanism for inducing firms to move. Finally, we find that wage bill subsidies, which are not much used by the Korean government, are more efficient than the land price subsidies which are frequently granted, but that the empirical evidence regarding infrastructure investments is inadequate to form firm judgements about their relative merit.

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CHAPTER I

Introduction

South Korean economic policy gives much attention to industrial location. The rationales for this concern are numerous: the proximity of the capital city, Seoul, to the North Korean border makes industry around the capital particularly vulnerable; congestion and pollution in Seoul lead some to think the city is too densely configured; and regional disparities in living standards frequently raise questions about the appropriateness of the Seoul region's economic dominance. But even more striking than the many reasons offered for government intervention in industrial location decisions is the variety and number of devices the government uses to influence locational choices. Mandates, prohibitions, tax breaks, loan guarantees, grants, land price reductions, promises of public infrastructure investments, wage bill subsidies, all are found in the grab bag of carrots and sticks used by the national government in its efforts to alter the spatial outcomes of the freely working market places.

In a random survey[1] of 141 Seoul region establishments that had moved, eleven different government programs were cited as having affected the firms' location decisions. One cannot help but ask both whether some of these policies are

1. The World Bank/Seoul National University Project Survey of 500 manufacturing establishments, of which 141 had moved within the Seoul region.

better than others, and under what circumstances one policy is preferable to another.

Most radically, one might ask whether the Korean government should try to influence location decisions at all. Unfortunately, there is no carefully articulated conceptual framework for analyzing the full effects of industrial location policies; moreover, a perusal of the theoretical literatures on industrial spatial choice and on optimal city sizes suggests that an appropriate framework would be quite cumbersome and would yield little in the way of analytical insights. Henderson (1980) finds that models of optimal city size are very sensitive to small changes in households' tastes and firms' technologies; consequently estimates of what cities should look like will be quite unreliable given the state of the art of estimating tastes and technologies.

In any event, policy makers should be cautioned that location policies may not be able to much alter the spatial configurations of cities in market oriented economies. Despite the large number of relatively generous schemes offered by the Korean government, most intraregional moves by Seoul firms are conducted without involvment in government programs. Indeed, in the 1981 Korean national survey of manufacturing firms, 74 percent of the firms that had moved reported they had done so primarily for operational reasons; only 12 percent reported that they had moved primarily in response to government subsidies or relocation mandates.

If extensive location policies such as those found in Korea have only marginal impacts on the location decisions of firms, one must expect that governments, without virtually abandoning free market mechanisms, cannot greatly alter the spatial configurations of their manufacturing sectors.

Potentially more fruitful than asking whether to move a firm from A to B, is to ask "How should we move a firm from A to B?" This is in fact the question a policy maker is more likely to pose to economists. Ought government subsidize the interest rates paid by a firm if it moves, or ought government offer subsidize land prices instead? And when is a subsidy on wages to be preferred to a public investment in sewerage or roads? In Korea, and throughout the developing world, industrial location is a politically charged issue, and politicians are unlikely to turn over to technicians any decision but the how of it.

But the how of it can still be economically important. Simulations reported below show that subsidizing interest rates enough to induce a firm to relocate can sometimes be twice as costly as subsidizing the price of land to the level which to induces the same relocation decision! But this gets us ahead of ourselves. Before we can evaluate or appreciate the results of such simulations, we need to work our way through the theoretical and empirical exercises that underlie them. This is the task of the coming chapters.

CHAPTER II

A Framework for Analysis[2]

Successful industrial location policies induce a firm that would have chosen one location, A, to choose some other location, B, which the government prefers. The government policy must overcome any cost or profit advantage site A enjoys. The essential economic question is "How costly is it for government to achieve a switch in the relative profitability of site B vis-a-vis site A?" Or, in choosing among alternative policies, the question becomes "Which politically feasible policy most cheaply overcomes site A's advantage?"

Many economists' likely first response to these questions is to argue that a simple cash payment to the firm, one just large enough to offset site A's advantage, is the most efficient, (i.e., least costly) policy. However, there is a certain naivete in this response. The political process often restricts the policies available to government; cash payments by government to private firms for cooperating in government policies is one type of plan that is frequently politically unacceptable. Even when direct payments are not completely out of the question, their political costs may outweigh their economic advantages.

2. The framework presented here was first developed in "Here, There, Where" A Strategy for Evaluating Industrial Relocation Policies in Korea" by Michael Murray, World Bank Report No. UDD-6 Project No. RPO 672-58.

The argument in favor of cash grants is that they leave the firm, once it has moved to B, with its incentives intact to produce its output as cheaply as possible at site B. Many other policies do not share this virtue.

1. Location Distortion

All policies that induce the firm to locate at B "distort" the location outcomes of the free market. And such distortions are not costless. The firm had reasons for initially preferring site A; either revenues would be less at site B (so consumers place less value on the firm's product at B), or costs would be higher at site B (so that more of society's resources are absorbed in producing the firm's output if the firm locates at B). In either case, the decline in profits in going from A to B reflects a real social cost of locating at B rather than A; this social cost we refer to as a "location distortion" caused by a policy that causes the firm to locate at B rather than A.

Countering this social cost of using site B are the social benefits of having the firm at B rather than at A, the benefits (reduced congestion, greater national security, or whatever) which motivated the government policy in the first place. A fundamenatal criterion for good policies is that these social benefits outweigh the social costs.

The costs of relocation may either be borne by government or be imposed on the firm. For example, if site A is $100 more profitable than site B, a lump sum government subsidy of, say, $150 to the firm will induce the firm to relocate, but the firm might also locate at B if the government prohibited it from choosing site A. In both cases, there is a social cost of $100 entailed by the move, but that cost is borne by government in the former case and by the firm in the latter case.

Notice that in the subsidy case, treasury costs exceed the social costs by $50. In such a case the subsidy scheme has two components; one is a relocation grant of $100 compensating the firm for its lost profits, and the other a pure transfer of $50 from the treasury to the firm. Knowing the profitability of the two sites permits one to assess what part of a given relocation subsidy is needed to bring about the change in location and what part is a pure transfer to the recipient.

The profitability differences between locations can arise from differences in output or input prices, from location specific tax liabilities, and from differences in the quantities of fixed inputs (public or private) available at each site. Further, these differences may arise from differences in transportation costs to and from markets, from comparative advantages of the locations themselves, from immobile private investments made in the past, or from past government decisions to invest in social overhead capital.

Because the differences between sites have specific roots, governments frequently respond with specific policies tailor-made to overcome the locational differences. This in part accounts for the plethora of relocation policies used by many governments. Some industrial location policies offer transportation subsidies to reduce the disadvantage of remote locations. Some policies subsidize the wage payments to labor to offset higher labor costs in less developed regions. Others subsidize capital costs to compensate for a lack of capital already in place. Still other policies offer to increase the public provision of goods or services to close the gap between more and less developed locations.

2. Production Distortion

These specific compensatory policies (and others like them) differ from the prohibition or cash subsidy policies described above. They not only induce the firm to choose B rather than A, but they also alter either relative factor prices or relative input availabilities at site B. Consequently, these policies may also distort the production decisions of the firm after it does locate at B.

A firm prohibited from locating at A will choose the cheapest possible way to produce its output at B. On the premise that market prices reflect marginal social costs, this implies that the firm will minimize the social cost of producing its output[3]. However, if the government location policy alters factor prices from their market levels, the bundle of inputs chosen by the firm to minimize its own outlays will no longer minimize the social cost of production;

3. The market prices paid for inputs by the firm reflect only the private cost of those inputs. However, if there are no externalties in the use of the inputs, and no market imperfections such as monopoly power in the sale of the inputs, then the private costs mirror the social costs of the inputs.

the difference between the lowest cost at which production at B could be achieved, and the cost of the resources actually chosen by the firm given government policies, is what we refer to as the "production distortion" caused by the policies. Any such "production distortion" will increase the total social cost of the location policy beyond the cost of the "location distortion" already discussed.

For illustration, consider a firm whose output would be the same at B as at A, so that differences in profit opportunities arise from differences in costs. The firm would choose a particular bundle of inputs, X^o, if it were to operate at B and face market prices, $P_B{}^m$, for inputs. However, if input prices paid by the firm were altered by the location policy, the firm would choose a different bundle of inputs, X^s, (for example, a wage subsidy to the firm would induce the firm to use more labor and less of some other inputs). The true value of the resources used by the firm under the subsidy scheme would be

$$\sum_{i=1}^{n} P_{Bi}{}^m X_i{}^s,$$

i.e., their cost reckoned at market prices. But the output <u>could</u> have been produced for as little as

$$\sum_{i=1}^{n} P_{Bi}{}^m X_i{}^o,$$

i.e., the costs the firm would have incurred had it faced market prices. Consequently, the social cost of the production distortion would be the differences between these two sums.

3. <u>Comparing Policies</u>

In general, the social benefits government envisions from an altered spatial pattern of industrial activity must be balanced against both components of the cost of relocation, the "location distortion" and the "production distortion." However, when comparing two policy devices that would achieve the same reordering of industrial location, the production distortion becomes the only relevant consideration since the location distortions are identical. Below, primary attention focuses on the production distortion aspect of relocation policies because it is the production distortions that will determine the answer to a policy maker's query, "Should I undertake policy X or policy Y to get firms to locate at B rather than A?"

Location distortions do not, however, drop out of the picture altogether. Each potentially successful subsidy policy must provide a firm with enough benefits to overcome site B's cost disadvantage; it is the location distortion that will determine this threshold level for each policy option. A policy maker can't simply ask, "Which is cheaper, to subsidize capital purchases ten cents on the dollar or land purchases fifteen cents on the dollar?" If ten cents on the dollar for capital purchases won't make the firm move, it is irrelevant that this policy would be cheaper. And if fifteen cents on the dollar for land purchases is more costly because it is overly generous--ten cents would suffice to induce the firm to move--then we still don't know which is better, subsidizing capital or subsidizing land. The relevant question is "Which is cheaper, a price subsidy on capital that just overcomes the cost advantage of A, or a price subsidy on land that just overcomes the cost advantage of A?"

Price subsidies are not the only tools used by the Korean government. The relevant question may also take the form "Which is cheaper, a price subsidy on capital that just overcomes the cost advantage of A, or social infrastructure investments at B that just overcome the cost advantage of A?"

Subsidizing factor prices or spending government monies on plant or infrastructure are succinct phrases that actually apply to many of the industrial location policies found in Korea. A review of several of these policies will serve to illustrate how one might analyze specific policies.

(1) Investment tax credit for new plant and equipment at the new location. This policy is in essence a reduction in the price of capital goods. Its effect will be to increase the use of these inputs relative to labor and other inputs. It will confer greater benefits on firms which use more capital and on firms which find it easier to substitute capital for other inputs.

Analyzing the social cost of this investment tax credit thus entails two steps. First, the differences in profitability between the old and new site must be computed to ascertain the "location distortion" induced by the policy.

Second, the production distortion resulting from an inappropriate input mix must also be calculated; this requires comparing the true value of inputs chosen by the firm with the value of the inputs which would be chosen if the firm were not confronted with an artificially low price of capital.

(2) Relocation Assistance Funds provided in proportion to the value of the plant at the previous location. Since these grants are independent of factor usage at the new location, they induce no "production distortion." Obviously these grants confer greater benefits on firms whose usage of capital is greater than others, but to the extent that the firm's plant is immobile, these greater benefits accompany greater opportunity cost in abandoning the old site. Analyzing the social cost of this measure only requires a calculation of the location distortion of effect.

(3) Capital gains tax exemption on the properties (plant and land) disposed of at the previous location. Again there is no production distortion induced since the grant is independent of factor choices at the new location. Consequently the primary question is whether the treasury cost much exceeds the minimum cost required to induce the firm to move.

Notice that capital gains are likely to be only loosely tied to the immobility of the firm. Consequently, unlike the relocation assistance funds, these exemptions are unlikely to offer greater benefits to firms for whom moving is more costly. Indeed, firms with immobile, specialized capital are likely to suffer capital losses in abandoning their former site (unless, of course, they simply sell to someone else who will engage in the same specialized activity, thereby largely thwarting the intent of the policy.) Consequently, this measure is likely to confer the largest benefits on those who need it least, and the smallest benefits on those who need it most.

(4) Income tax exemptions for individuals whose entire family relocates with the firm. This measure effectively lowers the wage rate which must be paid by the firm, since it at least partially compensates the employees for relocating with the firm. The measure raises several possible scenarios.

First, it is possible that some workers will refuse to relocate and will change jobs. They may judge that the prevailing wage in the new location, even when untaxed, is too low to compensate them for switching locations.

Second, it is possible that some workers will relocate with their employer and accept a wage at or below the prevailing wage in the new location. These workers may judge that the tax break makes the new location better than the old. If the workers must keep with the same employer to receive the tax break, then the employer need only pay them the minimum necessary to induce them to move; if the workers need only relocate to receive the tax break, then the employer will have to pay them the prevailing local wage.

In the latter case, this subsidy has no "industrial location effects" as such, it is a labor force location policy. In the former case, the wage savings accruing to the firm are an industrial relocation incentive, as such. If the firm hires local workers as well as relocated workers (of a particular type), then the marginal wage faced by the firm is the local wage, and there is no "production distortion"; if the firm uses only relocated labor, then the marginal wage is less than the local wage, and there are production distortions.

A third possibility is that workers will neither relocate nor change jobs, thus foregoing the tax break. This outcome requires that the wage paid by the firm at the new site compensates the workers for any added commutation costs. This could come about in one of three ways. First, the labor force at the new site may already be drawn from the current locale of this firm's workers, so the market wage at the new location is already high enough to compensate for the needed travel. Second, the firm's relocation from the old site may lower the wage at that site enough so the wage at the new site is now attractive enough to induce workers to commute from the old site to the new. And third, the firm's relocation to the new site raises the local wage at that site enough to compensate for the added travel, but moving is still not attractive. The assumption that the firm's location decision alters market wages complicates the analysis considerably, since one then has to treat input prices as non-parametric. In the absence of strong evidence to the contrary, it seems reasonable to treat each firm as small relative to the entire market.

However, extending the analysis later to account for some degree of factor price responsiveness is not to be discarded until more definitive empirical evidence is available.

It should be noted that the income tax is itself an intervention in the market place, and that therefore the market wage may not equal the marginal social cost of labor. This measurement issue lies beyond the scope of the present analysis.

(5) Exemption of local property taxes at the new location. This measure lowers the prices of land and improvement vis-a-vis other inputs. It can be expected to distort both location and production. As with the income tax, one must ask about possible divergences between market and social marginal costs induced by the taxes in the first place.

(6) 500 percent tax penalty for those who construct new plants or expand existing facilities in predesignated restricted areas. To the extent that this policy induces firms to locate elsewhere, it incurs only location distortions, since it doesn't alter factor prices at the new location, and the burden of the cost falls on the firm as foregone profits. However, to the extent that the policy fails, and firms either do not produce output which would have been produced, or continue to build or expand in the penalized area, there will be production distortions. Whether the distortions occur in the form of reduced output or altered inputs will depend on how the assortment of income, property

and registration tax penalties cumulatively influence factor prices.

(7) Loan guarantees for construction at the new site. This policy lowers the price of capital and thereby induces both location and production distortions. Its effects are similar to those of the investment tax credit.

(8) Special housing and consumer loans for employees of the relocated establishments. These have effects akin to those of the income tax break for households, although if they require distortions in the consumer's desired consumption patterns they may not benefit the consumer dollar for dollar.

(9) Local Industrial Development All of the above measures amount to cash grants or input price subsidies to the firms. An alternative set of mechanisms are provided for in Korea under the Local Industrial Development Law of 1969. Under this law local industrial districts can be designated and are then the targets of several government supports.

Government will pay for replotting the land, for road construction and for the development of an industrial water supply system. Further, land may be granted by the government to the developer. The provision of such services can lower the costs of firms and thereby enhance the attractiveness of one site vis-a-vis another. As indicated above, and detailed below, such in-kind subsidies to firms do not pose any special analytical problem. The gravest difficulty is empirical. It is very difficult to develop suitable measures of the availability and quality of public services and social overhead capital provided to firms by government. Consequently, our empirical assessments of the worth of such ventures are only suggestive.

In closing this section, I draw attention to a fundamental conceptual problem which is highlighted above in the analysis of several of the specific Korean location policies. The analysis of social cost given here assesses the cost of moving a given firm from site A to site B. However, the true concern of the planner is not this firm per se, but rather employment, or a general type of economic activity, or a specific technological process (say one that pollutes). Without a clear sense of what it is that planners wish to move from site A to site B, it is difficult to completely assess any policy. For example, the capital gains tax exemption plan noted above is likely to draw firms which rely heavily on capital rather than labor. If employment relocation is the goal of the policy, then this measure will appeal least to some of the firms planners would most wish to move. Our empirical analysis of alternative input subsidies should differentiate among industries to see if the heterogeneity of technologies across industries is sufficient to require heterogeneity in optimal industrial location policy as well.

4. Economic Principles

Several important economic theorems offer qualitative guidance in assessing alternative location policies. A brief summary of these theorems here will prepare us well for the quantitative examination of alternative policies in the coming chapters. (Proofs of these theorems, and several generalizations of them, are contained in Appendix A.)

The first theorem says that if a policy maker is limited to subsidizing the price of a single input to induce the firm to choose B over A, then it will minimize social cost to subsidize an input which (a) is used extensively by the firm and (b) is a poor substitute for other inputs. The latter condition ensures that lowering the price of this input will not much change the use of other inputs from what it would otherwise be. The former condition ensures that the price of the subsidized good will not have to be lowered much to confer a subsidy large enough to counter site A's profit advantage.

To illustrate these points, consider two firms that currently use very different amounts of land, but would add equal increments to the land they use if the price of land were to drop $100 per acre. To grant the same total subsidy payment to both the firms would require offering a <u>larger</u> price (per acre) break to the firm which uses less land, and therefore that firm would increase its use of land more than the other, thereby incurring a larger distortion in factor usage.

Alternatively, consider two firms with the same initial land use, but one of whom is more sensitive to changes in the price of land. The more sensitive firm will alter its factor usage more when the price of land is changed, and will therefore incur a greater distortion from optimal factor usage.

The second theorem says that if a policy maker is limited to increasing the provision of one public input (e.g., public transportation) then it will minimize social cost to increase the provision of an input which (a) the firm would be willing to pay much for and (b) is a good substitute for other inputs. The former condition ensures that not much of the publicly provided good need be offered to counter the profit advantage of site A. The intuition underlying the latter condition is that it would be pointless for government to spend its money purchasing inputs for the firm if the firm were not going to reduce its expenditures, hence the desirability of providing good substitutes for the firm's inputs.

A corollary to the second theorem is that if the publicly provided input is valued more at the margin than its marginal social cost of production, then provision of that public input will enhance, not lower, economic efficiency. If government can provide at a cost of ten dollars an input the firm values at twenty dollars (but cannot provide for itself), then there is a clear net social gain from government's incurring the ten dollar cost.

The notion that providing increases in publicly provided services might lower social costs has an analog among price mechanisms as well. If market input prices do not equal the marginal social costs of those inputs, the firms' market behavior will not minimize social costs of production. Consequently, there is room for lowering social costs by altering input prices with taxes or subsidies; government can use its policies to ensure that the firm faces marginal social costs of its inputs instead of marginal market costs, and can thereby induce the firm to minimize social costs while maximizing private profits with taxes or subsidies.

A third theorem which follows from one and two is that if two sites A and B differ in some one factor price, or some one publicly provided input, it may be better to subsidize a different factor's price or augment the provision of another service rather than to close the gap between the two sites.

For example, if high skill labor is more expensive at site B, it may be less socially costly to bring the firm to B by subsidizing unskilled labor at B than by subsidizing skilled labor. The determinants of the choice would be those given above: which kind of labor is less substitutable for other inputs and which is used more extensively.

Again for example: if roads from site B to the port city are far poorer than from site A to the port city, it might be a less socially costly way to bring the firm to B to allow that difference to remain and subsidize the price of high skill labor in site B, rather than simply improve the roads from B to the port city. The determination rests on rates of substitution, the level of skilled labor utilization, and the value of better roads to the firm. This example illustrates the fact that theorem three is in an important sense just a generalization of theorems one and two.

This third theorem is a weaker but more general version of the economist's usual sermon. Generally (but see the corollary above) economists argue that pure cash transfers (or mandates or prohibitions) are the least costly way to achieve a policy goal. Theorem three highlights that when those kinds of "first best" solutions are not politically feasible, "second best" solutions should be sought with care.

Taken together, these three theorems provide the theoretical underpinning needed to interpret the simulation results reported in chapter IV; they also focus our attention on key relationships to be examined in the empirical work of chapter III.

CHAPTER III

The Econometric Model

1. Introduction

The theorems described at the end of Chapter II identify the important economic parameters for assessing alternative subsidy schemes: the share of costs borne by each variable input ("factor shares"), the marginal value to the firm of each fixed input ("shadow prices"), and the substitutability of each factor for others ("elasticities of substitution").

We use the 1978 Korean census of manufacturing and the World Bank/Seoul National University Project Survey of manufacturing firms in the Seoul region to estimate the structures of technology for nine industrial categories based on two digit standard industrial codes (SIC's). By examining the factor choices of Korean firms as they face differing factor prices and differing quantities of fixed factors, we are able to estimate the elasticities of substitution among the various factors. Observation of variations in firms' costs across differing levels of fixed factors also permits us to estimate the shadow values of such inputs. Moreover, the surveys afford direct observations on the factor shares for several variable inputs.

These data are particularly rich in affording a look at the role of land prices in the cost structure of manufacturing firms. Few previous studies of manufacturing costs for any country have given land much attention.

It is important to keep in mind that ours is not an econometric exercise for its own sake. The shape and direction of the econometric investigations are dictated by the needs of our simulation model which evaluates alternative location subsidies. The available data are, in many respects, far from ideal, and one may be quite skeptical of any specific numbers obtained. However, in the context of a simulation model, in which sensitivity analyses are quite easy to conduct, it can often suffice to use econometric tools to obtain plausible "base" cases from which simulation analyses can begin.

If rough econometric work can put one in the right range for parameter values, simulations can then indicate either that further econometric sophistication is uncalled for -- more precision is not likely to alter the lessons from the exercise -- or that particular parameters are of especial importance and that further econometric efforts to pin down those parameters would be quite worthwhile. Where possible, we compare our econometric results with the findings of other studies of manufacturing, including studies for other developing countries and studies for the United States, using the survey reported in Reedy (1985).

2. The Model

An industry's technology is revealed in the production activities and in the cost structures of firms. By examining the relationship between output and inputs ("the production function") one can uncover the substitutability of factors and infer firms' optimal choices of inputs. Alternatively, by observing how firms' costs and factor choices vary with input prices, output, and levels of fixed inputs ("the cost function"), one can uncover the firms optimal choices of inputs and infer the substitutability of factors.

The cost function of the firm affords elegant derivations of the key economic theorems reported in chapter II. It also affords straightforward computations of the costs of alternative subsidy schemes. For these reasons we choose to rely on cost function specification in our empirical work.

Most generally, the cost function of the firm can be written as a function of the level of output and the prices of inputs. When some inputs are taken to be fixed, i.e., not determined by the firm, the function is referred to as a "restricted cost function," and the quantities of the fixed inputs are added to the variable list. Since we wish to assess the role of publicly provided inputs in the production process, we use restricted cost functions for the Korean industries.

Theoretical exercises, such as proving the theorems of chapter II, can use a very general specification of the restricted cost function. But for application, a concrete algebraic specification is required. Such a specification must be general enough to permit description of a wide variety of technological relationships. For example, the famous Cobb-Douglas functional form adapted to the restricted cost function problem yields

$$\frac{v}{y} = A \prod_{i=1}^{n} P_i^{a_i} \prod_{j=k+1}^{n} x_j^{b_j}$$

where v is the cost of variable inputs used, y is output, the p_i are variable input prices, the x_j are the quantities of the fixed inputs; and A, a_i, and b_j are parameters to be estimated. However, this would be too restrictive for our purposes since no matter what values are allowed for A, a_i, and b_j, the elasticities of substitution among the factors are always unity, precluding alternative degrees of substitutability among factors.

However, the chosen specification must also be simple enough to permit straightforward calculation of the many relationships of interest, such as shadow prices and factor demands. Furthermore, the parameters of the specification must bear a well defined relationship to available empirical relationships so that reasonable, realistic values can be assigned to them in simulations.

The specification chosen here is a restricted translog cost function. The translog specification of costs has been widely used in econometric studies of production and costs.[4] Here we adapt the specification to the case of restricted cost functions; the specification is attractive because it is empirically tractable, serves as a good approximation to many alternative specifications, and offers comparability with the empirical results of other studies. The functional form we use is:

4. See Christensen and Greene (1976) for an early cost function application.

$$\ln v = b + \sum_{i=1}^{k} a_i \ln P_i + \sum_{i=k+1}^{n} h_i \ln q_i + d\ln y + g(\ln y)^2$$

$$(1) \quad + \frac{1}{2}\sum_{i=j}^{k}\sum_{j=1}^{k} \alpha_{ij}\ln P_i \ln P_j + \frac{1}{2}\sum_{i=k+1}^{n}\sum_{j=k+1}^{n} B_{ij}\ln q_i \ln q_j$$

$$+ \sum_{i=j}^{k}\sum_{j=1}^{n} \gamma_{ij}\ln P_i \ln q_j$$

$$+ \sum_{i=1}^{k} \tau_i \ln P_i \ln y + \sum_{i=k+1}^{n} \theta_i \ln q_i \ln y$$

where $\alpha_{ij} = \alpha_{ji}$ and $B_{ij} = B_{ji}$.

where the p_i are variable input prices, the q_i are fixed input quantities, y is output, and v is the cost of variable inputs used. The structural parameters to be estimated are b, the a_i, the h_i, g, the α_{ij}, the B_{ij}, the γ_{ij}, the τ_i, and the θ_i.

3. Factor Shares, Shadow Prices, and Functional Restrictions[5]

Factor shares and shadow prices, two of the key economic parameters for assessing alternative subsidy schemes, are closely related to the cost function. If raising the quantity of a fixed input by one unit lowers the costs incurred by the firm for variable factors by x dollars, the firm should be willing to pay x dollars for that unit. Hence the shadow price of a fixed input is minus the derivative of the cost function with respect to that input.

Analogously, if the price of a variable input rises by one dollar, the firm's costs will rise by the quantity of that input being used by the firm. Hence, the demand for a

5. The non-technical reader may wish to skip this section.

variable input is the derivative of the cost function with respect to that input price.

If we take the derivatives of both sides of the translog function with respect to the variable input prices we get

$$S_i = \frac{P_i}{v} \frac{\partial v}{\partial P_i} = \frac{P_i q_i}{v} = a_i + \sum_{j=1}^{k} \alpha_{ij} \ln P_j$$

(2)

$$+ \sum_{j=k+1}^{n} \gamma_{ij} \ln q_i + \tau_i \ln y \qquad i = 1, \ldots, k$$

Since $P_i q_i / v$ is the factor share for the i^{th} factor, S_i is a factor share.

If we take the derivatives with respect to the fixed inputs we obtain:

$$- S_i^* = \frac{q_i}{v} \frac{\partial v}{\partial q_i} = \frac{q_i w_i}{v} = h_i + \sum_{j=1}^{u} \gamma_{ij} \ln P_j$$

(3)

$$+ \sum_{j=k+1}^{n} B_{ij} \ln q_i + \theta_i \ln y \qquad i=k+1, \ldots, n$$

where w_i is the shadow price of the i^{th} input, i.e., its marginal value to the firm. By analogy to S_i, we call S^*_i the quasi-factor share of the i^{th} fixed input. We use the expression "quasi-" to remind us that the value of the fixed input is being set to its shadow price, which may bear no relation to what the firm pays for the input, and also that the denominator is variable cost and does not include the shadow value of the fixed inputs.

Christensen and Greene (1976) have discussed a priori theoretical restrictions that might be placed on the parameters of an unrestricted translog cost function. If equation (1) were an unrestricted cost function, we would have the following restrictions:

$$\theta_i = 0,\ hi = 0 \qquad i = k+1,\ldots,n$$

(4) $$\gamma_{ij} = 0 \qquad i = 1,\ldots,k; \quad j = k+1,\ldots,n$$

$$B_{ij} = 0 \qquad i,j = k+1,\ldots,n$$

i.e., the q_i would not appear in the equations and there would be no quasi-factor share equations (3).

Christensen and Greene explain that homogeneity of degree zero of factor demands in factor prices (a direct consequence of cost minimizing behavior) would imply that if the restrictions in (4) hold, then

(5) $$\sum_j \alpha_{ij} = \sum_i \alpha_{ij} = \sum_i \sum_j \alpha_{ij} = 0.$$

Also, the fact that factor shares always sum to one requires

(6) $$\sum_{i=1}^{k} a_i = 1.$$

They further note that homotheticity of the production function underlying equation (3) requires that if the restrictions in (4) hold, then

$$\tau_i = 0 \qquad i = 1,\ldots,k$$

while homogeneity of that production function would require

$$g = 0$$

and linear homogeneity would add the further requirement that d = 1.

Since we are not emphasizing the effect of subsidies on output in the present study, returns to scale are less important to us than they might otherwise be. We assume (for convenience) that there are constant returns to scale in the production process when all inputs are considered. In instances in which different returns to scale seem appropriate, the simulation model can accommodate them by allowing a different technology to be set for large firms than for small firms. This limited flexibility suffices when each firm is viewed as having a fixed level of output, as is the case in this study.

When there are no fixed inputs, we use all of Christensen and Greene's restrictions; in the presence of fixed inputs, however, alternative restrictions are appropriate. Using a restricted cost function (one in which the restrictions in (4) do not hold) does not alter the restrictions (5) and (6). Factor demands are still homogeneous of degree zero in prices and the variable factors' shares still sum to one. However, the remaining restrictions offered by Christensen and Greene no longer hold.

Constant returns to scale in all inputs require that factor shares be changed when factor prices remain fixed while output and all fixed inputs are altered equiproportionately. This restriction implies that

(7) $$\theta_i = -\sum_{j=k+1}^{n} \gamma_{ij} \qquad i = 1,\ldots,k .$$

Like factor demands, shadow shares must also be homogeneous of degree zero in factor prices, so

$$(8) \quad \sum_{j=1}^{n} \gamma_{ji} = 0 \qquad i=k+1,\ldots,n \, .$$

Moreover, shadow shares are also unaffected by equiproportionate changes in output and fixed inputs so

$$(9) \quad \theta_i = - \sum_{j=k+1}^{n} B_{ij} \qquad i=k+1,\ldots,n \, .$$

When all these restrictions on share and shadow share functions are incorporated into equation (1), it can be seen that the only remaining influence on cost of equiproportionate changes in output and fixed inputs is through g, d, and the h_i. As in the unrestricted case, linear homogeneity of the underlying technology does require

$$g = 0,$$

but the constant on d is modified to become

$$(10) \quad d = 1 - \sum_{i=k+1}^{n} h_i \, .$$

These many restrictions on the parameters of the translog restricted cost function are both a boon and a bane.

They are a boon in that they reduce the amount of information required to estimate the cost structure. Given the slight variation in some variables of interest (most notably the interest rate) this parsimony is a real blessing.

However, when specifying variations from the estimated cost structures for use in the simulation model, the restrictions became a bane in that they prevent one from simply assigning values to all the parameters and getting on with the simulation; instead, one must carefully check that all the restrictions are faithfully applied so that the resulting cost structure is consistent with an underlying technology.

4. Data

The primary data source for this econometric work was the Korean Census of Manufacturing for 1978.

For our analysis, the key variables in the survey were: the number of production workers, wages paid to production workers, lot size, the value of the lot, the value of the building, the value of the structure, the value of the machinery, the value of output, the firm's two digit industry code and the four digit geocode for the firm's location.

These data were supplemented by the data on interest rates (the curb rate and the bank rate) gathered by Dr. Sang-Chuel Choe of Seoul National University, by data on the rate of inflation in Korea, and by data for the two largest industries, fabricated metals and textiles, gathered in the World Bank/Seoul National University Project Survey of the Seoul region. Our discussions with government and industry officials in Korea in early 1983 confirmed that in Korea small firms generally either finance their operations internally or rely on the curb market for funds; only larger firms have access to the bank rate without special provisions by the government. This fact motivated one major line of simulation work reported in chapter IV; it also suggested that the rental prices of assets would vary between small and large firms. Tests described below indicate that for analytical purposes it is appropriate to assume that firms below the mean size in their industry pay the curb rate, while larger firms pay the bank rate.

Specifying the role of interest rates in the study brings us to the proper measurement of prices in the cost function. Output is produced and costs are incurred by the firm anew in each period; both output and costs are flow concepts. Similarly, labor is hired anew each period; labor services are a flow concept. Capital and land, on the other hand, persist from period to period; they are stock concepts. To properly account for the role of land and capital in the firm's cost structure requires converting capital and land values. We define the value of capital or land times the real interest rate (the nominal interest rate paid by the firm less inflation) to be their respective rental values.

We choose our units of measure for capital so that the purchase price of capital is unity. Consequently, the rental price of capital is the real interest rate. Our treatment assumes a six percent rate of depreciation in the pricing of capital. Exploratory analysis indicated that other depreciation rates over a modest range would not much alter our empirical results.

We first tried to estimate the price of land by dividing reported lot value by reported lot size. Unfortunately, we found unbelievable variances in the price of land computed this way. We hypothesized that firm managers who answered the survey questions were unclear about either their lot values or their lot sizes and consequently gave error ridden answers to these questions. This hypothesis suggested that better estimates of the price of land could be obtained by computing the mean reported price of land in each four digit geocode area, a speculation that proved quite accurate.

Regressions of the log of land used by firms against the log of the prices of land as computed from the individual firms's responses to the survey frequently gave insignificant coefficients on the price of land. The same regressions using the mean price of land by geocode, however, repeatedly yielded significant land price coefficients of the appropriate sign. These relative performances of the two price measures were mirrored in their performances in other factor demand equations as well.

We wondered if perhaps the firm specific data, while not as rich as the geocode means, might not still contain information not found in the geocode means. To test this notion we tried instrumental variables estimators based on these two variables. The instrumental variables estimators were generally in the neighborhood of the estimates obtained with the geocode means in ordinary least squares estimators. This result is consistent with the notion that all the relevant information about the price of land is to be found in the geocode means. For this reason, we present only results based on the geocode means for land prices. Since, the purchase price of land varies by geocode, the rental price will also vary. We chose our units of measure for land so that the purchase price was unity in Seoul center city. This implies that at that location the rental price of land was the real interest rate.

Our findings regarding the land price variable, derived directly from reported lot value and lot size, led us to try two measures of land value in computing firms costs. First, we used reported land value; second, we used reported lot size times mean land price over the firm's 4 digit geocode. Our results are not very sensitive to which measure we look at.

The labor data provided by firms seems much more precise than the land data. Within industries, within geocodes, the variation in reported wage rates (production worker's wages divided by the number of production workers) was relatively much smaller than that in reported land prices. We believe this was due to better knowledge on the parts of managers about how many employees they have and what they pay them than about the size of their lot or its market worth. This is not unreasonable when one realizes that the former numbers are almost constantly subject to the manager's discretion while lot size is only infrequently altered and hence its price is of less pressing interest.

The geographic variation observed in land prices is considerable. There is a twenty-fold difference between land prices in central Seoul and those on the outskirts of the province. In wage rates, however, there is a much less pronounced pattern by geocode. Although there does seem to be a relationship between wage rates and locations, it is very slight, probably due to the dampening effects of commuting to and from the city center using transit provided by the firm.

We found no better measure for wage rates than those reported by the individual firms. Nonetheless, one must wonder about the extent to which the observed variations in wage rates across firms are spurious effects not mirrored in the firms factor choices; it strikes us as odd that in a cross section of firms, firms in a given industry would not be paying a single wage rate. However, we can point to the significant coefficients on the wage rate that are repeatedly of the right sign to argue that at least some of the observed effect is not spurious. But we must keep in mind that some of our coefficients may suffer some bias since spurious wage rate variation is not corrected for in our analyses.

In addition to using the geocode specific mean price for land, we relied on geocode specific means for other variables to provide instruments for use in two stage least squares estimations that we conducted. The rationale for this was that the behaviors of firms within a geocode were likely to be correlated, but that the individual peculiarities (the disturbance terms) of one firm would not be reflected in the behavior of their neighbors. Since we take factor prices and publicly provided inputs (and their proxies) as independent of the firm, the instrument's only role is to purge quantity of any bias due to the endogeneity rooted in quantity's relationship to costs and factor shares. Since the two stage least squares analyses did not appreciably differ from the ordinary least squares results, we report only the latter.

In addition to using land, labor, and capital as the firms inputs we toyed with using office workers as well as production workers as an additional labor category. However, both missing data and a high degree of multicollinearity between the two wage rates ultimately led us to reject this idea.

In our efforts to measure the effects of publicly provided inputs we examined: the proportion of a geocode's area devoted to streets, the proximity of the geocode to a highway, the electricity transmission capacity in the geocode, and the distance from the CBD (and an (inverse) proxy for accessibility). As will be seen below, the results from this exercise were disappointing for the most part. As a consequence, for the simulation models we had to resort to the use of proxies to obtain parameters for publicly provided inputs.

5. Estimation[6]

Equations (1), (2) and (3) all contain the parameters of our econometric model. Treating these equations jointly, and imposing the constraints on the parameters above, offers a general strategy for estimating our restricted translog cost

6. The non-technical reader may wish to skip this section.

function. In practice, however, we make no use of equation (3) since the shadow shares are unobserved.

It is at this juncture that our preoccupation with the simulation model begins to shape the empirical work. The share equations (2) and (3) suffice to estimate the γ_{ij} and α_{ij} which are sufficient (coupled with factor shares) to compute the substitution relationships among variable factors and between the variable and fixed factors. The cost function itself has the potential for augmenting the information drawn from equations (2) in three ways. First, more efficient estimates of the γ_{ij} and α_{ij} might be obtained. Second, the cost function offers information about returns to scale. And third, estimates could be obtained of the B_{ij} that inform us about the price elasticities of demand that would apply to the fixed factors if they were to become variable rather than fixed.

However, initial estimates from the two largest industries indicated that none of the advantages from focusing on equation (1) were forthcoming. When equation (1) was coupled with equations (2) we learned the following:

i) The theoretical constraints on the parameters implicit in their repeated appearances across the equations are not rejected in the data at hand;

ii) The parameter estimates of the α_{ij} and γ_{ij}, from equations (2) alone are nearly identical to those obtained from equations (1) and (2) taken together; and

iii) The B_{ij} cannot be estimated at all precisely with the data at hand; the standard errors on these parameters were always large.

Based on these preliminary findings, we chose to rely on equations (2) for estimating the elasticities that were of interest to us studying each of the nine manufacturing industries in detail.

Estimation of the parameters of equations (2) is straightforward but mechanically cumbersome. Note that each α_{ij} appears in two share equations, that for input i and for input j. Also recall that the share equations must always sum to one.

The adding up property implies that once k-1 shares are estimated, the k^{th} is known, so one share equation is dropped in the estimation procedure. (The empirical results are unaffected by which share equation is dropped.) The repetition of the α_{ij} across equations can be handled by physically "stacking" the equations--and the data--so that the equations are estimated by least squares procedures as if they were a single equation.

In stacked form, for example, the variable attached to coefficient α_{ij} would be $\ln P_j$ if the dependent variable were input i, and $\ln P_i$ if the dependent variable were input j. For coefficients appearing in only one equation, a similar treatment applies. For example, the variable attached to γ_{ij} would be $\ln q_j$ if the dependent variable were input i but would be a zero otherwise.

Ordinary least squares applied to such stacked equations yields maximum likelihood estimates of the parameters of the model under the usual OLS conditions. Instrumental variables estimators can also be applied to such stacked equations to obtain consistent parameter estimates under the usual conditions.

6. Summary of Estimation Results

Before reporting the results of a series of hypothesis tests, it is important to once again emphasize the relationship between the econometric model and the simulation model. The data base used in this study is a rich one, one with the potential to permit subtle distinctions to be made among alternative hypotheses. Indeed, with large sample sizes such as ours (ranging from 580 to 3418) one must expect that the data will "expose" the fact that the translog specification is at best only an approximation to the true cost function; many specific hypotheses about the model are likely to be rejected for this reason alone. However our real concern is not whether α_{ij}, say, is .01 or .011; rather, our concern is with differences in parameter values that are large enough to matter in the application of the simulation model. In this regard we find the model to be quite robust with respect to alternative sets of restrictions on the parameter values.

We found that when small firms were assumed to pay the curb interest rate and large firms the bank rate, the technologies estimated for the two groups were quite similar, although we could generally reject the hypothesis of identical technologies at the ten percent level. (Small firms were defined to be firms below the mean level of output for the industry and large firms were those above the mean level. Fiddling with the break point had no appreciable effect on our results.) Restricting large and small firms to pay identical interest rates, on the other hand, led to much more sharply distinguishable estimates of the cost function.

Conditional on pooling the large and small firms, more often than not we do not reject the hypothesis that all the theoretical restrictions implied by cost minimization hold. Even in the cases in which the constraints are rejected, the rejection is mild, suggesting that the translog is a reasonably good approximation to the true underlying cost minimization function. Similarly, conditional on the above restrictions, we generally fail to reject the hypothesis of constant returns to scale in all inputs.

The coefficients of the price variables are uniformly significant. The fixed input variables perform much less satisfactorily, however. The electricity, highway, and streets variables are each significant in fewer than ten percent of the cases. Only the distance measure is persistently significant. The distance measure reveals a persistent pattern of substituting away from labor and towards capital and land as accessibility declines, a result in accord with our intuitions.

Tables 1 and 2 contain the estimated α_{ij} and γ_{ij} from the translog cost share equations with all restrictions imposed. Land value is measured as reported lot size times the mean price of land for the 4 digit geocode area. Tables 3 and 4 contain the estimates with land value measured by the land value reported by the firm. The parameters estimated directly appear with t-statistics; the parameters derived from the estimated parameters using the parameter restrictions appear without t-statistics.

Table 5 presents mean elasticities of substitution from the models reported in Tables 1-4 evaluated at the mean factor shares for each of the nine industries (See Appendix B for the elasticity formulae.). Asterisks denote instances in which the estimated elasticity is negative, and hence zero is a better estimate. A limitation of the translog specification is that it permits concave regions in the isoquants of the underlying technology. In the simulation model we modify the translog so that elasticities of substitution never become negative, but rather stay constant at zero once they reach zero. For this reason, we simply report the estimated negative elasticities as the zeros they become in the simulation model.

Diane Reedy of the World Bank provided us with a survey of econometric estimates of elasticities of substitution in the U.S. and in developing countries (Reedy (1985)). That survey provides a useful benchmark to assess the plausibility of the elasticity estimates in Table 5. Table 6 reports the

TABLE 1

OWN AND CROSS PRICE INTERACTION TERMS (α_{ij})

IN THE TRANSLOG RESTRICTED COST FUNCTION*

	Food			Textiles		
	Land	Labor	Capital	Land	Labor	Capital
Land	.09	-0.06	-0.03	.12	-.07	-0.05
	(8.90)	(-8.47)		(9.13)	(-7.95)	
Labor	-0.06	0.08	-0.02	-.07	.12	-.05
		(7.50)			(10.61)	
Capital	-0.03	-0.02	0.05	-.05	-.05	.10
	Wood			**Paper**		
	Land	Labor	Capital	Land	Labor	Capital
Land	.12	-.07	-.05	.04	-.06	.02
	(9.13)	(-7.95)		(3.73)	(-8.04)	
Labor	-.07	.12	-.05	-.06	.10	-.04
		(10.61)			(9.25)	
Capital	-.05	-.05	.10	.02	-.04	.02
	Chemical			**Mineral**		
	Land	Labor	Capital	Land	Labor	Capital
Land	.08	-.04	-.04	.17	-.07	-.10
	(7.40)	(-7.07)		(9.32)	(-7.13)	
Labor	-.04	.10	-.06	-.07	.08	-.01
		(13.68)			(6.18)	
Capital	-.04	-.06	.10	-.10	-.01	.11

TABLE 1 (cont.)

	Basic Metal			Fabricated Metal		
	Land	Labor	Capital	Land	Labor	Capital
Land	.10	-.03	-.07	.07	-.04	-.03
	(5.83)	(-3.33)		(9.73)	(-9.74)	
Labor	-.03	.11	-.08	-.04	.11	-.07
		(8.05)			(20.93)	
Capital	-.07	-.08	.15	-.03	-.07	.10

	Other		
	Land	Labor	Capital
Land	.05	-.04	-.01
	(3.30)	(-4.39)	
Labor	-.04	.11	-.07
		(8.96)	
Capital	-.01	-.07	.08

*expressions in parentheses are t-statistics

TABLE 2

PRICE AND FIXED INPUT INTERACTION TERMS (γ_{ij}) IN TRANSLOG RESTRICTED COST FUNCTION BY INDUSTRY*

	INDUSTRY 31 Food				INDUSTRY 32 Textiles			
	Dist	Elec	Hwy	Strt	Dist	Elec	Hwy	Strt
Land	.045 (3.79)	.009 (1.00)	.003 (.43)	-.045 (-2.49)	.020 (2.60)	-.001 (-.33)	.008 (1.68)	-.017 (-1.46)
Labor	-.051 (-4.32)	-.014 (-2.74)	.001 (.11)	.039 (2.25)	-.025 (-3.35)	-.005 (-1.87)	-.002 (-.037)	.003 (.23)
Capital	.006	.005	-.004	.006	.003	.004	-.009	.016

	INDUSTRY 33 Wood				INDUSTRY 34 Paper			
	Dist	Elec	Hwy	Strt	Dist	Elec	Hwy	Strt
Land	.045 (3.20)	.001 (.16)	.018 (1.70)	-.039 (-1.84)	.011 (.72)	-.007 (-1.19)	.001 (.13)	-.013 (-.62)
Labor	-.048 (-3.41)	-.005 (-.86)	-.009 (-.92)	.023 (1.12)	-.058 (-4.14)	.008 (1.29)	.013 (1.31)	.034 (1.67)
Capital	.003	.004	-.009	.016	.047	-.001	-.014	-.021

	INDUSTRY 35 Chemical				INDUSTRY 36 Mineral			
	Dist	Elec	Hwy	Strt	Dist	Elec	Hwy	Strt
Land	.051 (4.18)	-.003 (.67)	.017 (2.40)	-.007 (.49)	.085 (4.16)	-.026 (3.46)	.016 (1.51)	-.009 (-.35)
Labor	-.059 (5.06)	.005 (1.29)	-.006 (-.93)	-.008 (-.56)	-.073 (-3.65)	.011 (1.60)	-.016 (-.55)	-.003 (-.14)
Capital	.008	-.002	-.011	-.015	-.012	.015	–	.012

TABLE 2 (cont'd)

	INDUSTRY 37 Basic Metal				INDUSTRY 38 Fabricated Metal			
	Dist	Elec	Hwy	Strt	Dist	Elec	Hwy	Strt
Land	.020 (.93)	-.005 (-.83)	-.003 (-.22)	-.029 (1.12)	.035 (4.35)	-.002 (-.63)	.003 (.63)	-.021 (-1.93)
Labor	-.048 (2.26)	-.003 (-.48)	.022 (1.65)	.046 (1.84)	-.048 (-6.06)	-.005 (-1.55)	.004 (.87)	.021 (2.01)
Capital	.028	.008	-.019	-.017	.013	.007	-.007	--

	INDUSTRY 39 Other			
	Dist	Elec	Hwy	Strt
Land	.033 (1.81)	.002 (.32)	-.001 (-.096)	-.016 (-.58)
Labor	-.055 (-3.14)	-.011 (-.62)	-.002 (-.21)	.038 (1.47)
Capital	.022	.009	.003	-.022

*expressions in parentheses are t-statistics

TABLE 3

ALTERNATIVE OWN AND CROSS PRICE INTERACTION TERMS (α_{ij}) IN THE TRANSLOG RESTRICTED COST FUNCTION*

	Food			Textiles		
	Land	Labor	Capital	Land	Labor	Capital
Land	.06	-.06	.002	.05	-.04	-.01
	(4.92)	(-7.34)		(6.41)	(-7.98)	
Labor	-.06	.12	-.06	-.04	.12	-.08
		(9.79)			(14.75)	
Capital	.002	-.06	.06	-.01	-.08	.09
	Wood			**Paper**		
	Land	Labor	Capital	Land	Labor	Capital
Land	.06	-.07	.01	.03	-.06	.03
	(3.06)	(-5.61)		(2.15)	(-6.98)	
Labor	-.07	.17	-.10	-.06	.12	-.06
		(9.94)			(9.50)	
Capital	.01	-.10	.09	.03	-.06	.03
	Chemical			**Mineral**		
	Land	Labor	Capital	Land	Labor	Capital
Land	.04	-.05	.01	.13	-.07	-.06
	(2.77)	(6.74)		(8.54)	(7.62)	
Labor	-.05	.13	-.08	-.07	.09	-.02
		(14.59)			(8.15)	
Capital	.01	-.08	.07	-.06	-.02	.08

TABLE 3 (cont.)

	Basic Metal			Fabricated Metal		
	Land	Labor	Capital	Land	Labor	Capital
Land	.02 (1.23)	-.03 (-2.49)	.01	.04 (4.55)	-.05 (-9.65)	.01
Labor	-.03	.13	-.10	-.05	.13	-.08
Capital	.01	-.10	.09	-.01	-.08	.07

	Other		
	Land	Labor	Capital
Land	.05 (2.43)	-.04 (-3.60)	-.01
Labor	-.04	.13 (8.55)	-.09
Capital	-.01	-.09	.10

*expressions in parentheses are t-statistics

TABLE 4

ALTERNATIVE PRICE AND FIXED INPUT INTERACTION TERMS (γ_{ij}) IN TRANSLOG RESTRICTED COST FUNCTION BY INDUSTRY*

	INDUSTRY 31 Food				INDUSTRY 32 Textiles			
	Dist	Elec	Hwy	Strt	Dist	Elec	Hwy	Strt
Land	-.001 (-.04)	.002 (.38)	-.019 (-2.35)	-.036 (-1.73)	.009 (1.01)	-.010 (-2.87)	.005 (.93)	.015 (1.10)
Labor	-.023 (-1.69)	-.004 (-.65)	.021 (2.52)	.060 (2.94)	-.022 (-2.54)	.011 (3.37)	-.001 (-.15)	-.012 (-.89)
Capital	.024	.002	-.002	-.024	.003	-.002	.018	-.017

	INDUSTRY 33 Wood				INDUSTRY 34 Paper			
	Dist	Elec	Hwy	Strt	Dist	Elec	Hwy	Strt
Land	.026 (1.30)	-.010 (-1.11)	-.038 (-2.51)	-.012 (-.41)	-.001 (-.07)	-.006 (-.82)	-.004 (-.36)	.015 (.63)
Labor	-.029 (-1.42)	.012 (1.38*)	.020 (1.38*)	.029 (.98)	-.044 (-3.42)	.007 (1.10)	-.006 (1.21)	.013 (1.14)
Capital	.003	-.002	.018	-.017	.0565	-.002	-.010	-.041

	INDUSTRY 35 Chemical				INDUSTRY 36 Mineral			
	Dist	Elec	Hwy	Strt	Dist	Elec	Hwy	Strt
Land	.016 (-.07)	.003 (-.82)	.012 (-.36)	-.00003 (.63)	.064 (1.19)	-.019 (.71)	.009 (1.50)	-.002 (-.0016)
Labor	-.054 (-3.42)	.008 (1.10)	.014 (1.21)	.026 (1.14)	-.044 (-3.74)	.007 (1.83)	-.006 (-1.41)	.013 (-.05)
Capital	.055	-.002	-.010	-.041	.028	-.010	-.006	-.01297

TABLE 4 (cont'd)

	INDUSTRY 37 Basic Metal				INDUSTRY 38 Fabricated Metal			
	Dist	Elec	Hwy	Strt	Dist	Elec	Hwy	Strt
Land	-.0;28 (-1.17)	.002 (.28)	-.012 (-.75)	-.033 (-1.16)	.012 (1.26)	.001 (.31)	-.004 (-.06)	-.017 (-1.31)
Labor	-.004 (-.17)	.003 (.45)	.011 (.74)	.072 (2.59)	-.053 (-3.97)	-.011 (-.96)	-.0002 (.93)	.046 (2.99)
Capital	.032	-.005	.001	-.039	.026	.002	-.0056	-.020

	INDUSTRY 39 Other			
	Dist	Elec	Hwy	Strt
Land	.032 (1.57)	.004 (.48)	-.002 (-.20)	-.021 (-.71)
Labor	-.053 (-2.70)	-.011 (-1.44)	-.0002 (-.02)	.046 (1.56)
Capital	.021	.007	.0022	-.025

*expressions in parentheses are t-statistics

TABLE 5

ELASTICITIES OF SUBSTITUTION

AMONG VARIABLE INPUTS

	Land/Labor	Land/Capital	Capital/Labor
Food	.23	.76	.76
Textiles	.42	.51	.54
Wood	.40	.41	.37
Paper	.38	.66	.59
Chemicals	*	1.45	.71
Mineral	.34	*	.86
Basic Metal	.54	*	.44
Fabr. Metal	.32	.52	.55
Other	.34	.57	.43

*indicates negative estimated elasticity.

median elasticity of substitution found by Reedy for each industry for the United States and for developing economies. (In computing the medians, studies of specific members of an industry, e.g., glass companies within the mineral industry, were excluded since it is unclear how estimates for more narrowly defined firms relate to the industry wide elasticities.)

Comparison of Tables 5 and 6 reveals that our estimates are persistently somewhat lower than the medians of other studies. However, all our values are well within the mid-range of numbers reported by others. One reason for caution in comparing our results with Reedy's is that the studies she reports for specific industries are generally two input production functions, labor and capital, while our results rely on three inputs. To check for the sensitivity of our results to this difference, we also estimated translog restricted cost functions for the three inputs taken in pairs. Table 7 reports the resulting elasticities of substitution. On the whole, the elasticities of substitution between labor and capital reported in Table 7 conforms more closely to those in Table 5 than those in Table 6, suggesting that the differences in our results are not rooted in our multifactor specification but either reflect a genuine difference in Korean technology from that used elsewhere, or are rooted in statistical quirks of the models and data used by ourselves and others.

TABLE 6

MEDIAN ELASTICITIES OF SUBSTITUTION BETWEEN CAPITAL AND LABOR IN REEDY'S SURVEY, OF U.S. AND AND DEVELOPING COUNTRY STUDIES

Manufacturing Industry	U.S.	Developing
Food	.75	.80
Textiles	.85	.59
Wood	.85	.89
Paper	.96**	1.0***
Chemicals	.83*	.88
Mineral	.98	.75
Basic Metals	.81	.86
Fabr. Metals	.72	.92
Other	1.1****	.81

*Chemicals .89, Petroleum .78, Rubber .82

**Paper 1.06, Printing .86

***Paper 1.17, Printing .87

****Manufacturing Sector as a whole, only 2 studies

TABLE 7

ELASTICITIES OF SUBSTITUTION FROM TWO VARIABLE FACTOR TRANSLOG RESTRICTED COST FUNCTIONS

Industry	Land/Labor	Land/Capital	Capital/Labor
Food	.42	.46	.74
Textiles	.53	.45	.67
Wood	.35	.13	.54
Paper	.34	.65	.69
Chemicals	.62	.41	.62
Minerals	.55	.12	1.15
Basic Metals	.33	.18	.35
Fabricated Metals	.46	.29	.57
Other	.50	.40	.43

Since few other studies have included land among the factors used by manufacturing firms, we have no checks within the literature for our elasticities of land with other factors. However, by using the World Bank/Seoul National University Survey of 500 firms in the Seoul region undertaken by the World Bank, we were able to obtain independent estimates of these elasticities for the two largest industry groups, textiles and fabricated metals. The results of this analysis are reported in Table 8. The elasticities for capital and labor and for land and labor are higher than from the larger Korean survey; those for capital and labor are in the range found in the Reedy survey. The elasticities for land and capital, however, are lower than those from the larger Korean survey.

The main lesson we draw from Tables 5-8 is that the potential for variability in estimates of elasticities of substitution is modest but genuine and that our simulations should reflect this potential by permitting variation in elasticities of substitution for all factors within the ranges reported in Tables 5-8. We also note with some satisfaction that when land and capital are focused on in isolation, the elasticities of substitution we estimate are positive in all cases. Moreover those elasticities are lowest, and generally quite low, in those cases in which the multi-factor translog obtained negative elasticities of substitution between land and capital when evaluated at mean factor shares. This is quite in accord with our decision in the simulation model

TABLE 8

ELASTICITIES OF SUBSTITUTION IN KOREAN MANUFACTURING USING AN ALTERNATIVE SURVEY OF MANUFACTURING FIRMS

	Land/Labor	Land/Cap	Cap/Labor
Textiles	.61	.27	.72
Fab Metals	.57	.14	.77

below to impose zero elasticities when negative elasticities are estimated; further it underlies our choice to use very low but non-zero values for the elasticity of substitution when establishing initial values in the industries with negative estimates. (This assumption simply assures us that in their initial position firms are not operating along non-strictly convex portions of their isoquants; it permits government policies to move firms to the cusps of the isoquants and, indeed, assures that initially these particular firms are near the cusp.)

7. Publicly Provided Inputs

The most disappointing aspect of the econometric results is the weak performance of the variables intended to reflect publicly provided inputs. There are several interpretations of these results that bear mentioning.

First, it is possible that the publicly provided inputs we examined do not substitute with land, labor, or capital either at all or sufficiently for the tradeoff to be measurable. That would leave open the question whether the inputs are substitutes for other inputs or simply sine qua non for production of certain goods, without which firms do not operate. Non-substitution between public and private inputs will serve not to exclude them altogether, but to limit the number and sizes of firms in an area, to the extent that the publicly provided inputs are not public goods (for example, electricity transmission capacity is a good from which users can be excluded and is a good that cannot be inexhaustibly consumed by as many users as want to use it).

An implication of this interpretation is that the volume of output from a particular location might be the only aspect of industry behavior influenced by public investments. If such is the case, studying the effects of location policy on quantities produced by firms becomes markedly more important than recognized in the simulations. Furthermore, the relationships among publicly provided inputs in supporting private production also become quite important since the goal of government would be to find the least costly configuration of public inputs that could support a given level of output--and that study would be quite separate from an analysis of private inputs if there is little or no substitution among public and private factors.

Second, it might be that publicly provided inputs only substitute to any appreciable degree for inputs that are not included in the present study, chiefly materials and energy. It is difficult to imagine that publicly provided inputs substitute <u>only</u> for materials or energy, but it is possible that the subactivities the firm would have to engage in to replace publicly provided inputs would, at the margin, be highly energy intensive. For example, a firm with trucks might impress the trucks for transit duty at the start and end of the day with little incremental capital costs, and hence the gasoline costs might loom large in the balance.

Third, it may be that although the publicly provided inputs found at any one site are exogenous to the firm, the fact that the firm chooses its location precisely because of its resources vis-a-vis other locations makes the "fixed" inputs truly variable (within a set restricted by local opportunities) for the firm. Such simultaneity of fixed inputs and variable input choices could lead to biases in our parameter estimates that mask the true relationships between variable and fixed inputs.

Fourth, the data at hand may be too coarse to permit extraction of the true underlying relationships. The data on firms is from 1978; the data on publicly provided inputs is from 1983. The rate of growth so diverse, that the five year lag in data could easily cover up the true relationships between the variable and fixed inputs.

Fifth, one might imagine that it was too ambitious to include all of the publicly provided inputs in the function, that multicollinearity among them would drown them all. Two considerations lead us to reject this possibility. First, the distance measure does manage to perform as one would anticipate. Second, runs in which various subsets of the public inputs were included led to no improvement in the performances of any of them. The only finding from these runs was a hint of positive correlations between electricity capacity and the usage of capital and labor. Such a finding is quite consistent with the endogeneity interpretation given above.

Finally, one might take the results at their face value. Perhaps no one publicly provided input has enough effect to be uncovered (just as one might be hard pressed to analyze a small subset of the workforce in a study like this), while the collection of publicly provided inputs still does have an appreciable effect on factor choices. And perhaps the overall level of public support for firms is closely enough correlated with distance from the city center for distance to serve as a proxy capable of reflecting the influence of publicly provided inputs as a whole.

Given the structure of our model, and the poor performance of other measures of publicly supplied inputs, we are left with little choice but to accept for now this last, optimistic, interpretation of our results.

The simulation model relies on the elasticities of variable factor demands with respect to fixed factors. Since in our exploration of the fixed inputs' influences we estimated these parameters directly using log linear factor demand equations (to see if those variables' poor performance was rooted in the restrictions of the translog specification) it is preferable when specifying the simulation model, to rely on those estimates for the elasticities of variable input demands with respect to the distance function. This judgment rests on two considerations. The first is the heavy computational burden of using the translog parameters to compute these elasticities that, as we demonstrated in Appendix B, depend on the unobserved shadow shares of the fixed inputs. Second, and more importantly, the double log specification yields elasticity estimates that are robust with respect to the relationship between fixed inputs and output. If fixed inputs are available equally for the production of each unit of output, the effective level of such inputs is proportional to output; at the other extreme, fixed inputs are available equally to each firm independently of output, and the effective level of such inputs is independent of output. The log specification yields the same elasticity with respect to fixed inputs in either case; only the interpretation of the output coefficient differs between the two. This robustness makes these elasticity estimates especially useful in the simulations.

Table 9 contains the elasticities of interest for each industry. The parameter estimates were relatively insensitive to the use of OLS or two stage least squares, as well as to the inclusion or exclusion of other measures of public inputs. It is worth noting that the log-linear factor demand equations gave further support to the assumption of linear homogeneity of the underlying technology since all but a few of the income coefficients were not significantly different from unity.

TABLE 9

DEMAND ELASTICITIES OF VARIABLE INIPUTS WITH RESPECT TO DISTANCE FROM THE CITY CENTER, BY INDUSTRY*

	Land	Labor	Capital
Food	.41(3.6)	.05(.7)	.30(2.4)
Textiles	.41(6.1)	.16(3.3)	.29(4.7)
Wood	.38(2.7)	-.11(1.0)	.03(.2)
Paper	-.09(.2)	.16(.7)	.56(1.7)
Chemical	.46(4.5)	-.04(.7)	.21(2.2)
Mineral	.72(3.2)	-.06(.6)	.41(2.4)
Basic Metal	.35(1.5)	.09(.6)	.57(2.7)
Fabr. Metal	.50(6.2)	.06(1.5)	.23(3.4)
Other	.66(3.1)	.69(3.6)	.16(.6)

*Figures in parentheses are t-statistics

CHAPTER IV

Simulating Alternative Policies

1. Introduction

The theoretical and econometric analyses of the previous chapters provide a groundwork for quantifying the costs and benefits of alternative subsidy schemes for Korean manufacturing. A major advantage of using simulation models in conjunction with econometric studies of technology is that one can explore the robustness of one's findings through sensitivity analyses. Moreover, rather than simply quantifying existing circumstances, simulations enable one to ask "what if" questions. Policy schemes outside the range of current arrangements can be considered side by side with schemes already in place. These comparisons enable us to judge the efficiency of present policies and to suggest how they might be improved.

2. Simulation Model

To influence firms' location decisions, the government must offer a subsidy that overcomes the cost or profit disadvantage of the site the government favors. No matter what input is subsidized, and no matter whether the price or the quantity is the avenue used for providing the subsidy, the subsidy must lower the firm's cost by some specific amount.

The simulation model offers two approaches to specifying the benefit required to move the firm. First, one can enter into the program a specific cost reduction that all subsidies considered must provide. The program will then calculate i) what price reduction for a given variable input or ii) what quantity increase for a given variable input or iii) what quantity increase for a given input that is otherwise fixed is needed to provide the firm the needed benefits.

Alternatively, one can specify that particular price reductions or specific quantity increases be given the firm and the program then calculates the cost reduction the firm would realize under such a scheme.

The cost of input subsidies to the government is generally larger than the benefits of such subsidies to the recipients. The difference between the cost of the subsidy and the benefit to the firm is the "deadweight loss" resulting from the distortions in incentives for the firm created by the subsidy schemes. A central function of the simulation model is to calculate the deadweight loss associated with each subsidy plan that is examined by the user. Among subsidies which all offer a firm the same level of benefits, the most efficient subsidy is the one for which the deadweight loss is smallest.

The simulation model presumes the firms' variable cost function is a restricted translog function of the form described in chapter III. When a particular subsidy scheme is provided by the user, the simulation program uses the cost function and the share equations to compute the firms' costs and factor demands with and without the subsidy scheme. By comparing the firm's unsubsidized costs with, in turn, the firm's subsidized costs and the full market value of the resources used by the firm under the subsidy, the program obtains the benefits and deadweight loss associated with the subsidy scheme. (See Appendix A for a formal representation of benefits, deadweight losses and the efficiency of alternative subsidy schemes.)

The simulation model has a more difficult task when provided as input a benefit level that subsidy programs must offer. The program solves for the specific subsidy the chosen input that yields the required benefits to the firm by conducting a binary search over possible values of the subsidy, after first discovering an upper bound for the subsidy level. Once the required subsidy scheme is ascertained, computation of benefits, subsidized factor demands, and deadweight loss are conducted as in the first mode.

One important practical problem must be confronted in the calculation of deadweight losses. The appropriate prices for computing deadweight losses are the marginal social values of the inputs. In applications it is common to rely on market prices to reflect marginal social values; in the absence of externalities, government intervention, and imperfect competition, this is the appropriate approach. But for publicly provided inputs, there is no market determined price to use as a proxy for marginal social value.

One obvious proxy for the marginal social value of publicly provided inputs would be estimates of their marginal cost to government. Such cost based values would probably be as acceptable as market prices if it were not for the shared nature of so many publicly provided inputs. Many firms benefit from improved road service to the urban center from some fringe business zone, for example, and consequently, an appropriate allocation of cost across the beneficiaries must reflect this sharing. It is, unfortunately, not easy to guess the appropriate fraction of marginal social cost to charge each firm in assessing the deadweight loss (or gains) associated with changes in fixed, publicly provided inputs.

We are lucky that this problem does not arise when we focus on subsidies for variable inputs, since for them we have acceptable proxy values for social costs and since such subsidies involve no changes in fixed inputs and hence no need to compute changes in the value of fixed inputs from unsubsidized to subsidized conditions. (In the one instance in which we have serious questions about appropriate marginal social prices for variable inputs--interest rates--we have well defined alternatives that permit us to analyze the cases sensibly.) But when we consider subsidies to fixed inputs, we face some serious dilemmas. In these cases we have chosen to develop several competing measures of deadweight loss (or indicators of inefficiency) that may assist us in evaluating these particularly nettlesome policies.

First, we assess deadweight loss using both the method described above and a user provided guess at the initial "social price" of the fixed input. Second, we assess deadweight loss on the assumption that the unsubsidized shadow price of the fixed factor is the true "social price" of the input. Finally, we report how the initially declared social value would have to change if the deadweight loss from the subsidy were to be held to zero.

The simulation model's final chores are to summarize the percentage changes in factor prices and quantities associated with the subsidy scheme in question and to express the deadweight loss as fractions of i) benefits to the firm, ii) total subsidy costs and iii) the firm's output.

One limitation of the model that should be noted here is that subsidy schemes are presumed to influence input mix but not output levels. It would be worthwhile in follow up research to adapt the model to permit output effects. However, to assess correctly the inefficiencies associated with output changes would require estimates of the market demands for manufactured goods, a task beyond the scope of this research.

Appendix D contains the documented Fortran code for the twenty subroutines that comprise the simulation model. Appendix B describes the theoretical relationships that enable the program to parameterize the translog restricted variable cost function from elasticities and factor shares provided by the user.

3. Parameterizing The Simulation Model

The first step in conducting simulations is the determination of what cases are of interest. In the present study this determination has two dimensions: the technologies to be analyzed, and the policies to be studied.

The ranges of factor share combinations and technological substitution relationships examined in this section are intended to be representative of what is found in the Korean manufacturing sector. The industry classification scheme used by the manufacturing survey that underlies the econometric work reported in chapter III divided the manufacturing sector into nine primary categories: food, textiles, wood, paper, chemicals, minerals, basic metals, fabricated metals, and "others". (The largest two of these nine industries are textiles and fabricated metals.) We also develop simulation cases in groups of nine, one corresponding to each industry.

The factors of production we have chosen to emphasize are labor, capital, and land. None of the subsidy plans in use in Korea subsidize materials inputs, so we refrain from including them in our analysis. Labor is the single largest remaining component of firm costs for all industries; capital is generally the next largest component. Capital and land, as we show below, are the inputs for which government subsidies are most important in Korea.

Across the nine manufacturing industries, mean annual firm costs for labor, land, and capital range from about 75 million won to about 145 million won per year, according to the survey data. However, to facilitate comparisons across simulations, we have chosen to lump the industries into two cost categories. The lower cost category, including the wood, chemicals, and "other" industries are taken to have a typical cost level of 100 million won per year. The remaining industries are taken to have a typical cost level of 125 million won per year.

The mean annual values of output in manufacturing are much higher than the mean annual costs of land, labor, and capital, reflecting the importance of factors of production that are not included in our analysis, such as materials, energy, and entrepreneurial risk taking. The variance in mean annual output values across industries is considerably greater than that in mean annual land, labor, and capital costs.

Table 10 reports typical output levels for medium, small and large firms in each of the nine industries. These figures correspond, approximately, to the means of output levels (i) for all firms in the 1978 Korean Census of Manufacturing, (ii) for firms below that industry mean, and (iii) for firms above that industry mean.

The shares of land, labor, and capital in annual costs vary appreciably across industries. The mean share of land ranges from about eight percent to about twenty percent; that for capital from about twenty to forty percent; and that for labor from about forty-five to seventy percent.

The computation of factor shares requires assumptions be made about the real rate of interest borne by firms for funds tied up in land and capital. Altering one's assumptions about that interest rate could alter the share of labor vis-a-vis land and capital, but the pattern of across industry factor

TABLE 10

TYPICAL FIRM SIZES BY INDUSTRY GROUP

ANNUAL OUTPUT IN MILLIONS OF WON

	SMALL[a]	MEDIUM[b]	LARGE[c]
Food	150	2250	18000
Textiles	100	800	3000
Wood	75	475	2500
Paper	150	900	2600
Chemicals	200	1400	6500
Minerals	100	625	2000
Basic Metals	300	1550	8500
Fabricated Metals	200	1200	6500
Other	150	475	1400

[a]Approximately the mean of all firms in the industry group whose output is below the mean output for the industry as a whole. (Based on firms analyzed in part II.)

[b]Approximately the mean output for the industry for all firms analyzed in Part II.

[c]Approximately the mean of all firms in the industry group whose output is above the mean output for the industry as a whole. (Based on firms analyzed in part II.)

share differences would be little affected. As we discuss below, it is plausible to believe that the shares reported here give lower bounds for mean labor shares and upper bounds for mean shares of land and capital.

Once again, to facilitate comparisons across simulations, we round factor shares in the cases analyzed below; the results are relatively insensitive to this rounding. Table 11 reports the typical factor shares for each industry that are used in the simulations.

The econometric work of others and that reported in chapter III yield estimates of the elasticities of substitution among land, labor, and capital for each of the manufacturing industries. Based on these estimates, we established the values found in Table 12 for these elasticities; again, rounding was used to achieve easier comparability across simulations; although the results are relatively insensitive to this rounding.

The empirical evidence for elasticities of the demands for land, labor, and capital with respect to publicly provided inputs is not at all precise. However, there is a strong negative correlation between distance from the city center and publicly provided infrastructure. Lee, Choe, and Pahk (forthcoming) used the World Bank/Seoul National University Survey to tally firms' assessments of the quality of various public services in the Seoul region. Table 13 is taken from that report. Using five rings, each further from the center of

TABLE 11

TYPICAL FACTOR SHARES BY INDUSTRY

	Land	Labor	Capital
Food	.15	.45	.40
Textiles	.10	.65	.25
Wood	.20	.60	.20
Paper	.10	.60	.30
Chemicals	.15	.55	.30
Minerals	.20	.60	.20
Basic Metals	.15	.60	.25
Fabricated Metals	.10	.65	.25
Other	.10	.70	.20

TABLE 12

TYPICAL ELASTICITIES OF SUBSTITUTION AMONG LAND, LABOR, AND CAPITAL

	LAND/LABOR	LAND/CAPITAL	CAPITAL/LABOR
Food	.25	.75	.85
Textiles	.40	.50	.85
Wood	.40	.40	.85
Paper	.10	1.45	1.0
Chemicals	.40	.65	.85
Minerals	.35	.10	1.0
Basic Metals	.55	.10	.85
Fabricated Metals	.30	.50	1.0
Other	.35	.60	1.5

TABLE 13

QUALITY OF URBAN INFRASTRUCTURE PROVIIONS
BY ZONE IN THE SEOUL REGION

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	All
		(Percent of Establishments in Each Ring)				
Electricity Never Interrupted	67	57	58	35	28	47
Water Never Interrupted	71	85	83	49	15	61
Excellent Telephone Service	100	76	53	46	58	56
Excellent Telegraph Service	71	41	14	25	5	26
Excellent Garbage Collection Service[a/]	19	11	10	7	10	9
Excellent Fire Protection	57	58	39	25	35	36
Number of Establishments	21	85	112	241	40	499

a/ 178 firms responded as using municipal services.

Source: K.S. Lee, S.C. Choe, and K.H. Pahk, "Determinants of Locational Choice of Manufacturing Firms in the Seoul Region: Analysis of Survey Results," The World Bank (forthcoming).

the city, with ring one including the central business district, the authors examined the quality of six publicly provided services. As is clear from the table, the perceived quality of services declines steadily with distance from the city center. Estimates of the elasticities of the demands for land, labor, and capital with respect to publicly provided infrastructure that exploit the strong negative correlation between distance from the city center and publicly provided infrastructure are reported in Table 14. As proxies for the elasticities with respect to infrastructure, we obtain elasticities with respect to distance from the CBD for manufacturing firms in the 1978 Korean Census of Manufacturing. These numbers provide at least useful initial values for analyses involving publicly provided inputs.

4. Simulation Scenarios

The second determination to be made in conducting simulations is the choice of questions to be addressed in the simulations. The World Bank/Seoul National University Project Survey provides strong evidence that central attention should be focused on credit subsidies and land price subsidies. Of the 141 firms in the survey that had relocated, 50 reported credit subsidies as the most important government subsidy available to them (8 more cited credit subsidies as being of some importance); 15 reported subsidized land prices as most important (32 more cited land price subsidies as being of some importance to them). No other subsidy mechanism was cited by more than 4 firms as most important.

TABLE 14

BASE VALUES FOR ELASTICITY OF DEMANDS FOR PRIVATELY PURCHASED INPUTS WITH RESPECT TO PUBLICLY PROVIDED INPUTS

	LAND	LABOR	CAPITAL
Food	-.40	-.05	-.30
Textiles	-.40	-.15	-.30
Wood	-.40	-.05	-.05
Paper	-.05	-.15	-.55
Chemicals	-.40	-.05	-.20
Minerals	-.70	-.05	-.40
Basic Metals	-.40	-.10	-.60
Fabricated Metals	-.50	-.05	-.25
Other	-.70	-.70	-.15

Based on elasticities with respect to distance from city center.

Credit subsidies are sometimes tied to capital loans and are sometimes allowed on loans used to purchase either land or capital. When the credit subsidy is tied to capital loans, it amounts to a reduction in the price of capital. As noted in chapter II, investment tax credits also provide a reduction in the price of capital. Consequently, when below we analyze credit subsidies tied to capital, we are implicitly also analyzing comparably valued investment tax credits. Such tax credits were cited by 14 of the 141 firms as being of some importance to them.

In chapter II we also noted that property tax exemptions were equivalent to land price subsidies for analytical purposes. 33 firms in the World Bank/Seoul National University survey cited property taxes as being of some importance to them.

Apart from the credit and land price subsidies, the subsidies most cited by firms as being of some importance were programs that introduce no production distortion: tax breaks on relocation expenses or capital gains on old plant and equipment (29 firms), exemption from registration and acquisition taxes (34 firms), and tax breaks on cash relocation grants (21 firms). However, a measure of the quantitative importance of these programs is that even taken together they are cited as being of most importance by only 11 firms. Credit and land price subsidies are clearly the programs deserving particular attention.

Loan guarantees are the most common form of credit subsidy in Korea, and it is these guarantees we shall focus on. These guarantees raise complex questions about the proper measurement of the market price of capital for the subsidized firms; we must address these if we are to properly analyze the efficiency of these subsidies.

In the following sections we analyze credit subsidies (emphasizing loan guarantees), land price subsidies, and the provision of public infrastructure. We close with some discussion of firm size and a summary of our analytical and empirical results.

5. Simulating Loan Guarantees

In the loan guarantee simulations we overlook fixed factors and restrict attention to land, labor and capital, analyzing the loan guarantees sometimes given to firms that relocate according to government wishes. Many firms moving to Banwoel, for example, received such subsidies.

A curiosity about these guarantees is that they do not offer lower interest rates than bank loans ordinarily afford; they only guarantee access. Since the large firms in each industry can generally get access to bank loans in any event, these guarantees attract only small and medium sized enterprises that would otherwise be unable to obtain such loans.

Firms unable to obtain bank credit must rely on either the curb market or internal financing. Since in our travels in the Seoul region we were repeatedly told by firm managers that curb market financing was prohibitively expensive for their enterprises, we conclude that the real curb interest rate provides an upper bound on the opportunity cost of capital to the firm shut out from bank financing. Consequently, on the supposition that the curb rate is the true opportunity cost of capital for firms receiving guarantees, analysis of the benefits and deadweight loss of loan guarantees provides upper bounds on both the benefits to the firms and the extent of deadweight losses.

-a. Curb Rate versus Bank Rate -

Table 15 presents the simulated benefits and deadweight losses from loan guarantees that lower the real interest rate faced by the firm from the curb rate to the bank rate for two cases: (1) the loans can be used for land or capital expenditures and (2) the guaranteed loans can only be used for capital expenditures. Most of the loan guarantees offered by the Korean government appear to be of the "capital only" variety; however some firms do receive unrestricted loan guarantees, so we examine both types.

Table 15 reveals that the general loan guarantees are most attractive to industries with lower labor cost shares, such as the food industry, and least attractive to industries with high labor shares, such as the "other" industry group. Loans for capital only are, as we would expect, more attractive to industries with higher capital shares (see Table 11): food, paper, and chemicals.

TABLE 15

BENEFITS AND DEADWEIGHT LOSSES FROM LOWERING THE INTEREST RATE FROM THE CURB RATE TO THE BANK RATE*

Subsidizing Land and Capital Loans

	Benefits** (B)	Deadweight Loss** (D)	B ÷ Cost***	B ÷ (B + D)
Food	58.33	13.84	.467	.808
Textiles	40.18	13.92	.321	.743
Wood	37.12	9.75	.371	.792
Paper	44.58	16.42	.357	.731
Chemicals	40.44	11.80	.404	.774
Minerals	46.73	13.22	.374	.779
Basic Metals	47.21	16.31	.378	.743
Fabricated Metals	40.87	16.32	.327	.715
Other	31.88	18.75	.319	.630

TABLE 15 (cont'd)

Subsidizing Capital Loans Only

	Benefits** (B)	Deadweight Loss** (D)	B ÷ Cost***	B ÷ (B + D)
Food	43.46	17.25	.348	.716
Textiles	28.63	13.75	.229	.676
Wood	18.13	8.22	.181	.688
Paper	36.86	21.87	.295	.628
Chemicals	26.99	12.20	.270	.689
Minerals	23.06	11.22	.184	.673
Basic Metals	27.42	10.96	.219	.714
Fabricated Metals	30.14	17.14	.241	.637
Other	23.44	20.31	.234	.536

* Curb rate taken as marginal social cost of loan

** Millions of won per year

*** 125 million won per year for all industries except wood, chemicals and other for those three costs are 100 million won per year. (see text p. 67-68 for discussion.)

Within an industry, deadweight losses will rise as benefits rise since greater benefits require greater distortions in prices. However, deadweight losses do not uniformly rise with benefit levels across industries because of differences in the cost functions across industries. For a striking example, deadweight losses are greater in the industry least favored by general loan guarantees (the "other" industry group) than in the most favored industry (the food industry).

-b. Loan Guarantees versus Alternative Subsidies -

Rather than offering firms loan guarantees, the government could offer subsidies on other inputs that would be equally valued by the firm. As noted above, land price subsidies are frequently used by government; the large cost share of wages also suggests that wage bill (price of labor) subsidies should be considered, too. Our question is whether such alternative schemes would be more or less efficient than loan guarantees. Since the value of the interest subsidy depends on whether loans are for land and capital or for capital alone (see Table 15 for the differences), alternative policies must be examined at two different levels of generosity in these comparison.

The simulation model conducts these analyses by beginning with the benefit levels given in Table 15 from the interest rate reduction schemes. The computer program then calculates how deep a subsidy on another input's price (the price of land, for example) would yield the firm those same benefits.

The value of all inputs chosen by the firm under the new subsidy scheme is then compared with the lowest cost at which the firm could produce its output given market prices. The difference is the deadweight loss associated with the subsidy scheme.

Table 16 compares the loan guarantees with several alternative subsidy mechanisms that yield equal benefits to the firms. Subsidies on the price of land only, the price of labor only, and the price of capital only are reported (the restricted loan guarantee is itself a subsidy on the price of capital only, so that comparison is not given.) Since each subsidy scheme matches the unrestricted or restricted loan guarantee in benefits, the only differences are in the "efficiencies" of the subsidy mechanisms, which we measure as the ratio of firms' benefits to the social cost (benefits plus deadweight loss) of the subsidy. The "interest rate subsidy" rows in Table 16 are the efficiencies reported in Table 15. The remaining rows are the corresponding efficiencies (benefits divided by the sum of benefits and deadweight loss) for the alternative subsidy plans.

In general, subsidies directly to land or labor are more efficient than unrestricted loan guarantees, while subsidies on capital's price alone are markedly less efficient. The roots of these differences are not all the same. Land price subsidies are particularly efficient primarily because of the relatively low elasticity of substitution of land for other inputs. Labor price subsidies appear to derive most of their

TABLE 16

COMPARISON OF LOAN SUBSIDIES WITH EQUALLY VALUED SUBSIDIES ON OTHER INPUTS WHEN LOAN SUBSIDY DROPS INTEREST RATE FROM CURB RATE TO BANK RATE

	FOOD	TEXTILES	WOOD	PAPER	CHEMICALS	MINERALS	BASIC METALS	FABRICATED METALS	OTHER
Land and Capital Loan Subsidy									
Efficiencies*									
Loan Subsidy	.808	.743[g]	.792[g]	.731[g]	.774[g]	.779[g]	.743[g]	.715[g]	.630[g]
Land Subsidy	.958[gm]	.981[gm]	.967[gm]	.936[gm]	.950[gm]	.991[gm]	.975[gm]	.992[gm]	.985[gm]
Labor Subsidy	.663	.912	.877	.869	.818	.870	.862	.904	.909
Capital Subsidy	.577	.518	.330[g]	.550	.487	.273	.436	.502	.427
Capital Only Loan Subsidy									
Efficiencies*									
Loan Subsidy	.716	.676	.688	.628	.689	.673	.714	.637	.536
Land Subsidy	.944[gm]	.973[gm]	.935[gm]	.924[gm]	.927[gm]	.983[gm]	.957[gm]	.989[gm]	.980[gm]
Labor Subsidy	.786	.944	.954	.899	.897	.950	.933	.936	.937

* Efficiency = Benefits ÷ (Benefits + Deadweight Loss)

g The subsidized input demand (land if several inputs subsidized) became perfectly inelastic at a price above the subsidized price.

m The subsidy required a negative price on the subsidized input.

advantage from having a higher cost share than capital; in the one industry (Food) with a higher cost share for capital than for labor, the labor subsidy is <u>less</u> efficient than the unrestricted loan guarantee.

However, it is important to note that the unrestricted loan guarantee subsidies are large enough to require quite deep subsidies of only land or only capital if the benefits from the unrestricted loan guarantees are to be matched. Indeed, in most instances one would have to put a negative price on land to match the guarantee. Needless to say, such a strategy would be politically untenable. Since this difficulty may be an artifact of using the curb rate, which is only an upper bound on the true opportunity cost of credit, we examine alternative cases below. However, even at this most generous level, subsidies to labor costs appear a viable and more efficient alternative to interest subsidies.

Guarantees for loans on capital alone are less efficient than land or labor subsidies yielding equal benefits to the firm. Given the greater efficiencies of land or labor subsidies relative to capital subsidies as alternatives to unrestricted guarantees, this result is not surprising. However it is somewhat surprising that "capital only" loan guarantees are always some ten percent or so less efficient than unrestricted loan guarantees, despite the fact that the unrestricted guarantees offer roughly half again as large benefits to the firms.

The explanation for this seeming anomaly is that the subsidy to land that differentiates the restricted and unrestricted loan guarantees is highly efficient, raising the overall efficiency of the unrestricted guarantees above that of the restricted guarantee. The root of this efficiency is that as the price of land falls markedly (as it does under the unrestricted guarantee plan), most firms virtually run out of opportunities for substituting land for labor and capital. When the elasticity of substitution between land and other factors falls to zero, further subsidization of land results in no additional deadweight loss. This effect leads to a high average efficiency for large subsidies to the price of land.

-c. Half the Curb Rate versus Bank Rate and Alternatives Revisited -

The curb rate provides an upper bound on the opportunity cost of capital to small and medium sized firms. Perhaps a better guess of the true opportunity cost would be the mid-way point between the bank and curb rates of interest. Tables 17 and 18 are patterned after Tables 15 and 16 but are based on the assumption that typical small and medium sized firms face an interest rate half way between the bank and curb rates. Table 17 makes clear why so many firms cite credit subsidies as being of great import to them. The benefits from either unrestricted or "capital only" loan guarantees are very high relative to the firms' costs.

Comparisons between Tables 16 and 18 confirm the rather general result that <u>within</u> industries the degree of

TABLE 17

BENEFITS AND DEADWEIGHT LOSSES FROM LOWERING THE INTEREST RATE TO THE BANK RATE FROM HALF THE SUM OF THE BANK AND CURB RATES*

Subsidizing Land and Capital Loans

	Benefits** (B)	Deadweight Loss** (D)	B ÷ Cost***	B ÷ (B + D)
Food	43.98	5.66	.352	.886
Textiles	29.79	5.73	.238	.839
Wood	28.95	4.54	.290	.865
Paper	32.94	5.45	.263	.858
Chemicals	30.67	5.46	.307	.849
Minerals	33.04	5.47	.288	.868
Basic Metals	35.62	7.61	.285	.824
Fabricated Metals	29.92	6.20	.239	.828
Other	22.59	6.86	.226	.828

TABLE 17 (cont'd)

Subsidizing Capital Loans Only

	Benefits** (B)	Deadweight Loss** (D)	B ÷ Cost***	B ÷ (B + D)
Food	29.85	6.02	.239	.832
Textiles	19.61	5.26	.157	.788
Wood	12.48	3.22	.125	.795
Paper	24.67	8.17	.197	.751
Chemicals	18.60	4.69	.186	.799
Minerals	15.77	4.32	.126	.785
Basic Metals	19.08	4.36	.153	.814
Fabricated Metals	20.28	6.39	.162	.761
Other	14.81	7.21	.148	.673

* Half the sum of the bank and curb rates taken as marginal social cost of loan

** Millions of won per year

*** 125 million won per year for all industries except wood, chemicals and other for those three costs are 100 million won per year. (see text p.67-68 for discussion.)

TABLE 18

COMPARISON OF SUBSIDIES WITH EQUALLY VALUED SUBSIDIES ON OTHER INPUTS WHEN LOAN SUBSIDY DROPS INTEREST RATE TO BANK RATE FROM HALF THE SUM OF THE BANK AND CURB RATES

	FOOD	TEXTILES	WOOD	PAPER	CHEMICALS	MINERALS	BASIC METALS	FABRICATED METALS	OTHER
					Land and Capital Subsidy				
					Efficiencies*				
Loan Subsidy	.886[g]	.839[g]	.865[g]	.858[g]	.849	.868[g]	.824[g]	.828[g]	.767[g]
Land Subsidy	.988[gm]	.974[gm]	.958[gm]	.916[gm]	.936[gm]	.989[gm]	.967[gm]	.989[gm]	.979[gm]
Labor Subsidy	.782	.941	.915	.913	.878	.911	.907	.936	.939
Capital Subsidy	.722	.660	.461	.667	.637	.456	.604	.640	.548
					Capital Only Loan Subsidy				
					Efficiencies*				
Loan Subsidy	.832	.788	.795	.751	.799	.785	.814	.761	.673
Land Subsidy	.983[gm]	.962[m]	.914	.891[gm]	.898[g]	.975[g]	.940[g]	.985[gm]	.968[gm]
Labor Subsidy	.871	.964	.970	.939	.936	.968	.957	.960	.962

* Efficiency = Benefits - (Benefits + Deadweight Loss)

g The subsidized input demand (land if several inputs subsidized) became perfectly inelastic at a price above the subsidized price.

m The subsidy required a negative price on the subsidized input.

inefficiency associated with a specific type of subsidy declines with the generosity of the subsidy. The only exceptions are land subsidy alternatives, the efficiency of which, as explained above, rises once substitution possibilities are exhausted.

The lesser subsidies in Tables 17 and 18 are not enough lower than those in Tables 15 and 16 to make land subsidies a viable alternative, despite their attractive high efficiency. The share of land in total costs is so small that government would, in general, have to pay firms for the land they use to match the benefits of loan guarantees.

Furthermore, the reduced generosity closes the gap somewhat between unrestricted loan guarantees and subsidies to labor costs, although the latter are still generally preferable--and clearly dominate "capital only" loan guarantees. Similarly, the gap between "capital only" and unrestricted loan guarantees is narrowed somewhat, though the former are still markedly less efficient despite their lesser benefits.

-d. Loan Guarantees and Inefficient Credit Rationing -

There is an alternative perspective that one might take on loan guarantees. The above analyses assumed the true marginal cost of credit to small and intermediate size firms is the curb rate or some other rate above the bank rate. In this view, allowing these firms access to bank credit rates distorts true factor prices and induces inefficiencies in operations. But it is more plausible to argue that the small and intermediate size firms face an artificial barrier to bank borrowing and that the true marginal cost of credit to these firms is the bank rate, not the curb rate.

If this alternative view is correct, as seems likely to the author, small and intermediate size firms suffer increased costs and society suffers deadweight losses from the "artificial" credit prices faced by these firms in the curb market or elsewhere.

Tables 19-20 report the costs increases and the deadweight losses suffered from artificial credit constraints imposed on typical firms in each industry, as well as what those deadweight losses would be if only land were affected (i.e., under "capital only" loan guarantees). Table 19 is premised on firms paying the curb rate when denied bank financing; Table 20 is premised on them paying halfway between the bank and curb rates.

Columns 1 of Tables 19-20 report the increase in costs incurred by typical firms when the interest rate rises artificially from the bank rate. Columns 2 in those tables report the deadweight losses induced by these artificially high interest rates. Columns 3 express that deadweight loss as a function of costs in the absence of the artificially high interest rates. Column 4 reports the decline in deadweight loss (expressed as a fraction of costs in the absence of artificially high interest rates) if firms were given "capital only" loan guarantees so they only faced the artificially high interest rate on loans for land purchases.

TABLE 19

COST INCREASES AND DEADWEIGHT LOSSES FROM ARTIFICIALLY HIGH INTEREST RATES ON LAND AND CAPITAL LOANS OR CAPITAL ONLY LOANS, GIVEN ARTIFICIAL RATE IS CURB RATE

High Interest on Land and Capital

	Increased Costs*	Deadweight Loss*	Percentage Cost Increase**	Deadweight Loss as Fraction of Initial Cost (L_2)
Food	58.33	8.34	.875	.125
Textiles	40.18	8.27	.474	.098
Wood	37.12	6.42	.590	.102
Paper	44.58	8.43	.554	.105
Chemicals	40.44	7.23	.679	.121
Minerals	46.77	8.36	.597	.107
Basic Metals	47.21	9.95	.607	.128
Fabricated Metals	40.87	8.96	.486	.106
Other	31.88	9.74	.468	.143

TABLE 19 (cont'd)

High Interest on Land Only

	Increased Costs*	Deadweight Loss*	Percentage Cost Increase**	Deadweight Loss as Fraction of Initial Cost (L_1)	(L_1-L_2)
Food	14.87	3.21	.223	.048	.077
Textiles	11.55	2.13	.136	.025	.073
Wood	18.99	3.06	.302	.049	.053
Paper	7.72	1.33	.096	.017	.088
Chemicals	13.84	2.95	.226	.050	.071
Minerals	23.67	2.65	.302	.034	.073
Basic Metals	19.79	4.06	.254	.052	.076
Fabricated Metals	10.74	1.47	.128	.017	.089
Other	8.43	1.29	.124	.019	.124

* Millions on won per year
** Initial cost is what costs would be at bank rate of interest

TABLE 20

COST INCREASES AND DEADWEIGHT LOSSES FROM ARTIFICIALLY HIGH INTEREST RATES ON LAND AND CAPITAL LOANS OR CAPITAL ONLY LOANS GIVEN ARTIFICIAL RATE IS HALF THE SUM OF THE BANK AND CURB RATES

High Interest on Land and Capital

	Increased Costs*	Deadweight Loss*	Percentage Cost Increase**	Deadweight Loss as Fraction of Initial Cost (L_1)
Food	43.98	4.27	.543	.053
Textiles	29.79	4.39	.313	.046
Wood	28.95	3.71	.407	.052
Paper	32.94	4.32	.358	.047
Chemicals	30.67	4.03	.442	.058
Minerals	36.04	4.50	.405	.051
Basic Metals	35.62	5.54	.399	.062
Fabricated Metals	29.92	4.51	.315	.047
Other	22.59	4.83	.292	.062

TABLE 20 (cont'd)

High Interest on Land Only

	Increased Costs*	Deadweight Loss*	Percentage Cost Increase**	Deadweight Loss as Fraction of Initial Cost (L_2)	(L_1-L_2)
Food	13.95	2.56	.172	.032	.021
Textiles	10.18	1.59	.107	.017	.029
Wood	16.47	2.24	.232	.032	.020
Paper	8.27	1.49	.090	.016	.031
Chemicals	12.07	2.24	.174	.032	.036
Minerals	20.27	1.81	.228	.020	.031
Basic Metals	16.54	2.73	.185	.031	.031
Fabricated Metals	9.64	1.10	.101	.012	.035
Other	7.77	1.03	.100	.013	.049

* Millions on won per year
** Initial cost is what costs would be at bank rate of interest

The most important numbers in Tables 19 and 20 are the deadweight loss figures. The higher credit costs paid by small and medium size manufacturing firms are, after all, income to someone else, and therefore not a real loss to the Korean economy. By contrast, the deadweight losses are real subtractions from the general economic welfare.

The average deadweight loss in Table 19 is approximately 11-12 percent of land, labor, and capital costs; that in Table 11 approximately 5 percent. Since the small and medium size firms that are affected by credit restrictions account for as much as forty percent of all manufacturing production (based on estimates from the 1978 Korean Census of Manufacturing), the numbers in Table 19 translate roughly into a 4.5 percent increase in land, labor, and capital costs across all manufacturing due to the credit restrictions. The comparable figure from Table 20 is 2.0 percent. These figures presume that it is the bank rate that reflects the true marginal cost of credit to small and medium size firms in Korea.

The numbers in Tables 19 and 20 suggest two important lessons for Korean policy makers. First, artificial credit restrictions on the manufacturing sector do not come cheaply; the two to four percent of all manufacturing costs for land, labor, and capital is an appreciable social cost to be incurred from such policies. Second, given the presence of such credit restrictions, their relaxation is a promising approach to subsidizing firms as part of industrial relocation programs.

A third lesson worth drawing from Tables 19 and 20 is that restricted loan guarantees which only offer access to capital loans realize the greater part of the available windfalls. Such restricted access schemes could reduce the deadweight losses associated with credit restrictions by about two-thirds.

For analysts there is an important lesson to be found in comparing Tables 15 and 17 with Tables 19 and 20. Measuring the impact of loan guarantees on social welfare critically depends on which view of the true marginal cost of credit to small and intermediate firms is correct. Juggling elasticities of substitution and factor shares, as we do, for example, across industries, has relatively little impact on our assessments of the relative benefits and efficiencies of alternative policies, but shifting one's view about which interest rate is appropriately taken as the true marginal cost of credit, drastically alters the balance between benefits and deadweight losses.

For example, in Table 15, the efficiency of unrestricted guarantees ranges from .63 to .81 across industries, a spread of .18; but for unrestricted loan guarantees, the spreads <u>within</u> industries between the efficiencies in Table 15 and those implicit in Table 19 average about .50. (For example, from Table 19, a restricted loan guarantee to a typical food industry firm would lower the firms costs by 58.33 while at the same time reducing deadweight loss by 8.34. Thus, the efficiency measure applied to Table 19 yields an efficiency of 1.17, or .37 higher than reported in Table 15.)

The point is perhaps more forceful when one states it this way: "If the true social cost of loans to small and intermediate size firms is the curb rate or some other rate above the bank rate, subsidies to capital are the least efficient mechanisms for industrial relocation; but if the true social cost is the bank rate, capital subsidies are the most efficient mechanisms for industrial relocation."

-e. Low Elasticities of Substitution

Tables 15-20 are based on the elasticities of substitution given in Table 12. The capital-labor elasticities given there are indicative of the "majority view" based on the study of Korean manufacturing discussed in chapter III, studies of U.S. manufacturing and studies of manufacturing in developing countries surveyed by Reedy (1985).

In five instances, however, a minority view of the capital-labor elasticity was sharply below the majority. Usually the lower value arose from the specific study of Korean data described in chapter III (see Tables 5 and 7). Consequently, it is of interest to see how the findings of Tables 15-20 are affected by using markedly lower capital-labor elasticities in those five industries. Table 21 reports the alternative capital-labor elasticities used.

TABLE 21

ALTERNATIVE CAPITAL-LABOR ELASTICITIES OF SUBSTITUTION

	Capital/Labor
Textiles	.55
Wood	.40
Basic Metal	.45
Fabricated Metal	.55
Other	.45

Tables 22, 23, and 24 are derived in the same fashion as Tables 17, 18 and 20 except that the elasticities of substitution between capital and labor are set at the alternative, lower values. (Replications of Tables 15, 16, and 19 lead to similar qualitative results as reported here for 22, 23, and 24, so we do not report them.)

The lower elasticities of substitution between capital and labor bring a very slight decline in the differences between firms' costs under high and low interest rates. More substantial effects are seen when we look to deadweight losses.

As shown in Table 22 the efficiency of unrestricted loan guarantees rises some, especially for the "other" industry group (in which the largest elasticity change is made, from 1.5 to .45), if one takes the non-bank rate as marginal social cost. The efficiency of "capital only" loan guarantees goes up markedly; as we would expect since capital is the good that has become less substitutable for other inputs.

But Table 23 shows that increased efficiency of subsidized loans for capital expenses do not qualitatively alter the relative merits of subsidies on land, labor, and capital. Labor subsidies still tend to be the most efficient, with land subsidies slightly dominant over capital subsidies. However, the quantitative differences we see between land and capital subsidies make us doubtful if there is any good reason for choosing one over the other on efficiency grounds.

TABLE 22

TABLE 17 RESULTS USING ALTERNATIVE (LOWER)

CAPITAL-LABOR ELASTICITY

CAPITAL AND LAND

	Benefits* (B)	Deadweight Loss* (D)	B ÷ Cost	B ÷ (B + D)
Textiles	28.58	3.76	.229	.984
Wood	27.95	2.98	.279	.904
Basic Metal	34.22	5.50	.274	.861
Fabr. Metal	28.09	3.17	.225	.899
Other	19.57	1.82	.196	.915

CAPITAL ONLY

	Benefits* (B)	Deadweight Loss* (D)	B ÷ Cost	B ÷ (B + D)
Textiles	18.27	2.96	.146	.861
Wood	11.24	1.02	.112	.817
Basic Metal	17.42	1.47	.139	.922
Fab. Metal	18.27	2.96	.146	.861
Other	11.50	1.48	.115	.886

* Millions of won per year

TABLE 23

TABLE 18 RESULTS USING ALTERNATIVE (LOWER) CAPITAL-LABOR ELASTICITY

LAND AND CAPITAL

	TEXTILES	WOOD	BASIC METALS	FABRICATED	OTHER
EFFICIENCIES					
Loan Subsidy	.884	.904[g]	.861	.899[g]	.915[g]
Land Subsidy	.973[gm]	.957[gm]	.966[gm]	.988[gm]	.976[gm]
Labor Subsidy	.957	.941	.934	.960	.976
Capital Subsidy	.771	.957[g]	.948[g]	.775	.880[g]

CAPITAL ONLY

	TEXTILES	WOOD	BASIC METALS	FABRICATED	OTHER
EFFFICIENCIES					
Loan Subsidy	.861	.917	.922	.861	.886
Land Subsidy	.959[gm]	.917	.935[g]	.982[gm]	.959[g]
Labor Subsidy	.976	.982	.973	.977	.988

g The subsidized input demand (land if several inputs subsidized) became perfectly inelastic at a price above the subsidized price.
m The subsidy required a negative price on the subsidized input.

TABLE 24

TABLE 20 RESULTS USING ALTERNATIVE (LOWER) CAPITAL-LABOR ELASTICITY

LAND AND CAPITAL

	Increased Costs*	Deadweight Loss*	Percentage Cost Increase**	Deadweight Loss as Fraction of Initial Cost (L_1)
Textiles	28.58	3.17	.296	.033
Wood	27.95	2.71	.388	.038
Basic Metals	34.22	4.14	.377	.046
Fabricated Metals	28.09	2.69	.290	.028
Other	19.57	1.82	.243	.023

CAPITAL ONLY

	Increased Costs*	Deadweight Loss*	Percentage Cost Increase**	Deadweight Loss as Fraction of Initial Cost (L_2)	L_1-L_2
Textiles	10.31	1.61	.107	.017	.016
Wood	16.70	2.28	.232	.032	.006
Basic Metals	16.80	2.77	.185	.031	.015
Fabricated Metals	9.82	1.12	.101	.012	.016
Other	8.08	1.07	.100	.013	.010

* Millions on won per year
** Initial cost is what costs would be at bank rate of interest

The lower elasticities of substitution also lower the simulated deadweight losses associated with artificially raising the cost of credit from the bank rate to a higher non-bank rate. In Table 20, we found a 2 percent increase in the resource cost of land, labor, and capital in Korean manufacturing arising from such a policy. In Table 24, the comparable figure is 1.5 percent, with an especially large drop in the "other" industry group.

Nonetheless, 1.5 percent of manufacturing costs for land, labor, and capital is not a trivial amount, and the deadweight losses recorded in Tables 22 and 23 are also non-trivial. Consequently, we conclude that even if the substitution between labor and capital is at the lower end of what we might expect, differences in the efficiencies of alternative subsidy mechanisms should not be overlooked.

Since using the alternative, lower elasticity measures for the substitutability of labor and capital has not altered our comparisons among alternative policies, in the following simulation exercises we rely on the higher, "dominant", views on these elasticities.

6. Simulating Land Price Subsidies

Land price subsidies are the second most important relocation policy, according to firm managers. Most of these subsidies in the Seoul region are offered to firms that move to the new industrial city Banwoel. The absence of private land markets makes it difficult to assess the degree of these subsidies. However, from private discussions with local developers and from firm managers' assessments obtained in a small informal survey conducted by Dr. S.C. Choe of Seoul National University, we surmise that in 1985 the market value of land in Banwoel was about one half to one third the price in Seoul itself, with firms located in Banwoel actually paying only one fourth or one fifth of the market value.

To permit an analysis of the public provision of infrastructure as a policy alternative to land price subsidies we rely on a restricted cost function that includes land, labor, and capital as variable inputs and, as explained above, an inverse distance from the center of Seoul as a proxy for public infrastructure.

At a distance 2 km from the center of Seoul, the price of land is at the upper end of the price range that anecdotal evidence suggests for Banwoel. If the price of land varies to reflect differences in publicly provided infrastructure, the level of publicly provided infrastructure in Banwoel would be somewhat below that found 2 km from the center of Seoul. However, since land 2 km from the city center also benefits from better accessibility and greater privately provided infrastructure (such as agglomeration effects), the level of publicly provided inputs in Banwoel must be somewhat higher than its land price would suggest. For this reason we assume public infrastructure in Banwoel is equal to that found 2 km from the city center.

Because of our uncertainty about the elasticities between publicly provided and variable inputs, we conducted our analyses using both the elasticities reported in Table 14 and also elasticities equal to half those values (with the exception that elasticities equal to .05 were not further reduced). The estimated elasticities capture the cost savings associated with the better publicly provided infrastructure, better privately provided infrastructure (such as agglomeration effects), and better accessibility found closer to the city center. Since public policies cannot alter all of these items, the sensitivity of factor demands to publicly provided inputs is probably less than the elasticities of Table 14. This is the rationale for examining the lower elasticities.

The benefits and deadweight losses from a seventy-five percent land price subsidy for typical firms in each manufacturing industry are presented in Table 25; this subsidized land price, the market land price and the level of public infrastructure are all chosen with the intent of mimicking the land price subsidies offered firms in Banwoel. The table makes it obvious why so many firms find the land price subsidies important. The cost reductions realized by the firms range from ten to twenty percent of the firms expenditures on land, labor, and capital (see the third and seventh columns of Table 25). This is a generous level of benefits comparable to the benefits from "capital only" loan guarantees reported in Table 17 -- although well below the benefits from unrestricted loan guarantees. The efficiency of these land price subsidies varies markedly across industries

TABLE 25

BENEFITS AND DEADWEIGHT LOSS FROM 75 PERCENT LAND SUBSIDIES GIVEN HIGH AND LOW ELASTICITIES OF DEMAND FOR VARIABLE INPUTS WITH RESPECT TO FIXED INPUTS

	High Elasticity Specification				Low Elasticity Specification			
	Benefits (B)*	Deadweight Loss (D)*	B ÷ Costs	B ÷ (B+D)	Benefits (B)*	Deadweight Loss (D)*	B ÷ Costs	B ÷ (B+D)
Food	20.92	6.04	.166	.776	22.85	7.21	.174	.760
Textiles	13.83	2.80	.114	.831	15.11	3.51	.118	.811
Wood	22.21	3.55	.207	.862	24.33	4.90	.221	.832
Paper	16.16	7.60	.135	.680	16.25	7.27	.128	.691
Chemicals	16.71	4.64	.162	.782	18.27	5.73	.172	.761
Minerals	24.09	1.26	.191	.950	28.33	2.31	.212	.924
Basic Metals	24.75	6.17	.179	.800	22.75	5.29	.174	.811
Fabricated Metals	13.10	1.27	.105	.912	14.69	1.96	.114	.882
Other	9.57	1.88	.117	.835	11.29	21.41	.120	.824

* Millions of won per year

(see columns 4 and 8 of Table 25). The minerals industry, for which land is least substitutable for other inputs (see Table 25), has a very high efficiency with only a five percent deadweight loss. The paper industry, for which the estimated land/capital elasticity of substitution is very high, has deadweight loss of nearly one third. Table 26 compares this land price subsidy with equally beneficial subsidies on labor or capital prices. The qualitative results here should come as no surprise since the comparisons are similar in principle to those done for the restricted loan guarantee. However, two points are worth emphasizing.

First, altering the assumed responsiveness of variable input demands with respect to publicly provided inputs has little impact on what we say about the relative merits of alternative subsidies on variable inputs. Second, although labor price subsidies dominate both capital price and land price subsidies, land price subsidies do not appear nearly as attractive relative to capital subsidies as in the analysis of loan guarantees. The reason for this latter result is that in nearly all cases in Table 26, in contrast to the loan guarantee simulations, the demand for land does not become perfectly inelastic within the subsidized price range, and thus the average efficiency of subsidies is not driven up in the manner described in the analysis of loan guarantees. (Notice, however, that in Table 26, too, the efficiency of land subsidies is generally high when the demand for land becomes perfectly price inelastic (indicated by footnote g on

TABLE 26

EFFICIENCIES OF LAND, LABOR, AND CAPITAL PRICE SUBSIDIES
YIELDING BENEFITS EQUAL TO 75 PERCENT LAND PRICE SUBSIDY

High Elasticity* Specification

Price Subsidized:	FOOD	TEXTILES	WOOD	PAPER	CHEMICALS	MINERALS	BASIC METALS	FABRICATED METALS	OTHER
	EFFICIENCIES								
Land	.776	.831	.862[g]	.680	.782	.950[g]	.800	.912[g]	.835[g]
Labor	.917	.975	.939	.960	.944	.948	.942	.975	.962
Capital	.871	.839	.620	.808	.815	.589	.756	.833	.770

Low Elasticity* Specification

Price Subsidized:	FOOD	TEXTILES	WOOD	PAPER	CHEMICALS	MINERALS	BASIC METALS	FABRICATED METALS	OTHER
	EFFICIENCIES								
Land	.760	.811	.832	.691	.761	.924[g]	.811	.882[g]	.824[g]
Labor	.906	.972	.930	.960	.936	.934	.949	.971	.963
Capital	.869	.836	.583	.832	.807	.558	.745	.824	.743

g The subsidized input demand (land if several inputs subsidized) became perfectly inelastic at a price above the subsidized price.
m The subsidy required a negative price on the subsidized input.
* Elasticities in question are elasticities of variable input demands with respect to fixed input.

the Table). Only for the "other" industry group do we obtain land price subsidy efficiencies below ninety percent when the demand for land turns perfectly inelastic, and in this case it so happens that demand turns perfectly inelastic just barely above the subsidized price.)[7]

7. Simulating Publicly Provided Inputs

The most difficult and tenuous comparison we attempt is that between the land price subsidy of Table 25 and equally beneficial subsidies in the form of higher levels of publicly provided inputs. This comparison raises important measurement problems.

-a. Measurement Problems -

The measurement problems bear on both the price and the quantity of publicly provided goods. We shall discuss each in turn.

Identifying the marginal social cost of variable inputs is a much less nettlesome problem than finding a comparable social cost for fixed inputs. The market place offers a price for variable inputs; and even in the face of monopolistic elements in the economy, these market prices are likely to give a reasonable range for marginal social costs--and will often provide very good estimates. (Even in the face of artificial government requirements, for example, we are fairly confident that the marginal social cost of credit to small and

7. One might wonder if the difference in the land price subsidy efficiency depends critically upon the use of unrestricted cost functions in the loan guarantee analysis and restricted cost functions here. Appendix C explores this issue and suggests this is not the case.

intermediate firms lies between the bank and curb rates.) However, firms do not purchase publicly provided inputs, and the marginal social cost of such fixed inputs is much more problematic since we do not have a market in which to observe how much firms are willing to pay for these factors.

In our simulations we take two approaches to evaluating the marginal social costs of fixed factors. First, we evaluate these costs at a preset number that is provided to the simulation model by the user. In ideal circumstances this number would be based on cost studies that indicate how much government must pay to provide various levels of public services. But even in our less ideal circumstances, the use of a fixed base allows comparisons across industries and across firm sizes that a sliding scale of marginal costs could not easily accommodate.

Second, we evaluate the marginal social costs of fixed inputs at their initial marginal shadow value to the firm. That is, we compute the change in the firm's costs that would result from a one unit increase in the publicly provided input. This is the amount the firm would be willing to pay for that fixed input - the shadow value of the input. If publicly provided inputs had no "public goods" aspects, this would be the appropriate marginal cost so long as publicly provided inputs were available initially in an optimizing mix. It is this idealistic scenario that warrants the use of shadow values as an interesting basis for evaluating deadweight losses. It is important, however, to note two limitations in using shadow values in this way. First is the obvious point that publicly provided inputs are likely to have at least some public goods aspects, and consequently the conditions for Pareto optimality require marginal costs to be set to something besides the input's shadow value for a single firm. Second is a more important point. Differences in the shadow value of publicly provided inputs across industries, will yield incomparable deadweight loss estimates across industries if the deadweight losses are computed using the specific shadow price of publicly provided inputs for each industry as the value of fixed inputs. This arises because in such cases the social prices for computing deadweight losses would be different for each industry or output level.

-b. Publicly Provided Inputs Versus Land Price Subsidies -

Table 27 reports the efficiencies of land price subsidies (taken from Table 25) under the high and low elasticity of variable input demands with respect to fixed infrastructure. The table also reports the efficiency of equally beneficial subsidies in the form of increased infrastructure. The second and fifth rows provide efficiencies of the infrastructure subsidies premised on marginal social cost being equal to the initial shadow value of the fixed infrastructure for a firm in the industry. Since the shadow values differ from industry to industry, these efficiency measures do not permit cross industry comparisons. The third and sixth rows provide efficiencies of the infrastructure subsidies premised on a single, albeit arbitrary, social cost for fixed

TABLE 27

EFFICIENCIES OF LAND PRICE AND FIXED INPUT QUANTITY SUBSIDIES EQUAL TO 75 PERCENT LAND PRICE SUBSIDY

High Elasticity* Specification

	FOOD	TEXTILES	WOOD	PAPER	CHEMICALS	MINERALS	BASIC METALS	FABRICATED METALS	OTHER
Subsidy Mechanism:									
Land Price	.776	.831	.862	.680	.782	.950	.800	.912	.835
Fixed Inputs (Shadow Value[a])	.663	.768	.441	.763	.584	.692	.700	.712	.899
Fixed Inputs (Preset Value[a])	.789	.904	.301	1.008	.430	1.147	1.636	.621	2.166

Low Elasticity* Specification

	FOOD	TEXTILES	WOOD	PAPER	CHEMICALS	MINERALS	BASIC METALS	FABRICATED METALS	OTHER
Subsidy Mechanism:									
Land Price	.760	.811	.832	.691	.761	.924[g]	.811	.882[g]	.824[g]
Fixed Inputs (Shadow Value[a])	.441	.566	.299	.511	.355	.470	.506	.526	.815
Fixed Inputs (Preset Value[a])	.291	.335	.098	.404	.152	.435	.390	.274	1.02

g The subsidized input demand (land if several inputs subsidized) became perfectly inelastic at a price above the subsidized price.
a See text.
m The subsidy required a negative price on the subsidized input.
* Elasticities in question are elasticities of variable input demands with respect to fixed input.

infrastructure. These measures permit cross industry comparisons of relative efficiency but offer no insight into the actual levels of these efficiencies in any industry.

Despite the limitations of the infrastructure subsidy efficiency measures in Table 27, some insights persist. In particular, we see that the relative efficiency of subsidies in the form of higher fixed inputs depends crucially on the substitutability of the fixed inputs for variable inputs, just as the theoretical discussion of chapter II leads us to expect. The efficiency of fixed input subsidies drops markedly when the assumed elasticities of variable input demands fall in magnitude no matter how fixed inputs are evaluated. Second, from the second and fifth rows of Table 27 we conclude that unless the social cost of publicly provided inputs is well below the shadow value of those inputs to the firm, land subsidies sharply dominate increases in publicly provided goods for all industries. This conclusion can be strongly drawn if one judges the high elasticity specification to be an upper bound on the substitutability of publicly provided inputs for variable inputs.

-c. Publicly Provided Goods and Firm Size -

Just as nettlesome as the pricing of publicly provided inputs is their quantification. The difficulty here is not measuring government investments; using miles of road or megawatts of electricity transmission capacity--or even distance from the city center, are not unacceptable devices. But one must ask how firms of different sizes respond to government investment in a region. Most government investments offer benefits that can be realized anew with each increment to output, and consequently the input is, in effect, proportional to output--for example, every unit of output gets to the city center faster when the road system is improved. On the other hand, some public investments are more exclusionary in nature, each firm gets access to them without regard to the level of output--for example police surveillance deters breaking and entering from both small and large enterprises equally. In this view, publicly provided inputs are available in fixed quantity independent of the firms level of output.

In this section we do not explore in detail the consequences of externality or public goods aspects of publicly provided inputs. But we do explore the two extremes: benefits from publicly provided inputs accruing in proportion to output, and the effective levels of those inputs being independent of output.

Our cost model assumes that the technology is linearly homogeneous in <u>all</u> inputs, i.e., doubling both variable and fixed inputs will double output (and costs). Consequently, the percentage results in Tables 25-27 pertain to <u>all</u> output levels for the firm if publicly provided inputs yield their benefits in proportion to output: (i.e., if the quantity of publicly provided input at a given location is proportional to the firm's size). While we lean towards believing this view of publicly provided inputs, we recognize that some independence of the effective quantity of public inputs from firms' output levels is likely. Consequently in Tables 28-30 we recalculate the high elasticity specification results of Tables 25-27 for large and small firms under the hypothesis that the effective levels of government inputs in an area are independent of quantity produced. Such complete independence is an extreme that permits us to bound our results. The truth of the matter, however, is likely to lie much closer to Tables 25-27.

The simulations underlying our analysis of firm size and public infrastructure subsidies assume large firms have output and cost levels approximately equal to the means for firms in the industry which have outputs above the overall industry mean. The simulations assume small firms have output and cost levels equal to the means for firms in the industry that have outputs below the overall mean for the industry. Consequently, each industry has different low and high cost and output levels. This suggests we be cautious in comparing across industries within high and low output levels.

What we do want to focus on is comparisons across high and low output levels within industries and ask what results then generalize across industries. To facilitate comparisons across output levels we have assumed for Tables 28-30 that all firms pay the bank rate of interest. To interpret this specification it is suitable to say that the tables analyze the marginal effect of land price subsidies for firms that have already been given loan guarantees so long as the true

TABLE 28

BENEFITS AND DEADWEIGHT LOSS FROM 75 PERCENT LAND SUBSIDY GIVEN NO VARIATION OF FIXED INPUTS EFFECTS WITH OUTPUT

	LOW OUTPUT FIRMS		HIGH OUTPUT FIRMS	
	Benefits as a Fraction of Firm's Cost	Benefits as a Fraction of Subsidy Cost	Benefits as a Fraction of Firm's Cost	Benefits as a Fraction of Subsidy Cost
Food	.084	.983	.222	.702
Textiles	.076	.959	.144	.734
Wood	.099	.998	.303	.748
Paper	.179	.637	.108	.744
Chemicals	.078	.989	.227	.697
Minerals	.079	1.000	.299	.802
Basic Metals	.139	.906	.215	.742
Fabricated Metals	.042	1.000	.176	.716
Other	.102	.893	.132	.781

TABLE 29

EFFICIENCIES OF LAND, LABOR, AND CAPITAL PRICE SUBSIDIES YIELDING BENEFITS EQUAL TO 75 PERCENT LAND PRICE SUBSIDY GIVEN NO VARIATION OF FIXED INPUTS EFFECTS WITH OUTPUT

LOW OUTPUT FIRMS

PRICE SUBSIDIZED:	FOOD	TEXTILES	WOOD	PAPER	CHEMICALS	MINERALS	BASIC METALS	FABRICATED METALS	OTHER
Land	.983[g]	.050	.009[g]	.637	.989[g]	1.000[g]	.906[g]	1.000[g]	.893[g]
Labor	.981	.989	.982	.969	.584	.99	.983	.980	.953
Capital	.909	.874	.854	.427	.904	.529	.997	.538	.874

HIGH OUTPUT FIRMS

PRICE SUBSIDIZED:	FOOD	TEXTILES	WOOD	PAPER	CHEMICALS	MINERALS	BASIC METALS	FABRICATED METALS	OTHER
Land	.702	.734	.748	.744	.697	.802	.742	.916	.781
Labor	.816	.958	.864	.958	.882	.835	.859	.930	.970
Capital	.861	.819	.488[g]	.898	.755	.438	.829	.770	.579

g The subsidized input demand (land if several inputs subsidized) became perfectly inelastic at a price above the subsidized price.

TABLE 30

EFFICIENCIES OF LAND PRICE AND FIXED INPUT QUANTITY SUBSIDIES EQUAL TO 75 PERCENT LAND SUBSIDY GIVEN NO VARIATION OF FIXED INPUTS EFFECTS WITH OUTPUT

LOW OUTPUT FIRMS

SUBSIDY MECHANISM:	FOOD	TEXTILES	WOOD	PAPER	CHEMICALS	MINERALS	BASIC METALS	FABRICATED METALS	OTHER
Land Price	.983[g]	.959[g]	.998[g]	.637	.989[g]	1.000[g]	.906[g]	1.000[g]	.893
Fixed Inputs (Shadow Value[a])	.857	.863	.728	.800	.811	.808	.798	.873	.919
Fixed Inputs (Preset Value[a])	.034	.101	.058	.063	.055	.061	.132[g]	.035	.039

HIGH OUTPUT FIRMS

SUBSIDY MECHANISM:	FOOD	TEXTILES	WOOD	PAPER	CHEMICALS	MINERALS	BASIC METALS	FABRICATED METALS	OTHER
Land Price	.702	.734	.748	.744	.697	.802	.742	.716	.781
Fixed Inputs (Shadow Value[a])	.579	.672	.231	.785	.403	.498	.589	.494	.912
Fixed Inputs (Preset Value[a])	5.717	4.587	1.061	4.827	1.873	4.798	15.619	3.212	71.66

g The subsidized input demand (land if several inputs subsidized) became perfectly inelastic at a price above the subsidized price.

a See text.

social cost of credit is the bank rate, a quite realistic view of the situation in, say, Banwoel.

The first point to notice is in Table 28. Benefits from a land price subsidy rise as a fraction of firm costs as output rises, while the efficiency of the subsidy falls as output rises. This result appears to reflect the fact that land is a better substitute (according to Table 14) for the publicly provided inputs than are other inputs, so larger firms, being relatively more "starved" for publicly provided inputs (the ratio of fixed inputs to output falls with firm size under this specification's interpretation of publicly provided inputs), make a larger substitution towards land when land's price falls than do smaller firms. This shift raises both benefits and deadweight loss, but raises the latter by more.

The second point to note is from Table 29. The efficiencies of alternative subsidies on labor and capital fall as output rises. Large firms appear to have greater substitution possibilities among variable inputs than do smaller firms, and consequently show greater deadweight losses. This greater substitutability is also evident in Table 30 when we look at increasing the quantity of the publicly provided input. Consider the third and sixth rows in which the social cost of the fixed input is set equal to the marginal value of the fixed input for a typical size firm rather than for a small or large firm. Notice that when the social cost of the fixed inputs are set equal to this arbitrary single price for both large and small firms, the larger firms always value the fixed input more highly, and therefore suffer smaller deadweight losses. Indeed, the marginal value larger firms put on the fixed inputs is so large that deadweight losses would be negative ("deadweight gains") if the marginal social cost were initially set to the marginal valuation typical size firms place on the fixed input. It is this result that suggests characterizing large firms as being "starved" for the fixed input in these simulations.

Indeed, in general, if the publicly provided inputs are independent of the firms output level, one will always find that individual firms disagree about the optimal level of public investment. Large firms will always want a higher level of public investment than small firms. However, if firms use publicly provided inputs in intensities proportional to output, we will tend to find the disputes about public investment breaking along industry lines (due to differences in technologies) rather than by size of firm.

8. Summary

The simulations reported in the previous section suggest several lessons for policymakers and make clear several important avenues for future research.

Since the simulation evidence indicates that the variations in efficiencies and subsidy benefits across industries are small relative to the variations across types of subsidies, we shall dwell on the latter here.

If, as seems likely to us, the inability of small and medium size firms to obtain bank loans is an artificial constraint resulting from government policies, the message from the simulations is clear. Loan guarantees are a highly cost effective location policy tool. Perhaps twenty percent of the subsidy payments granted to firms through loan guarantees will be recouped through the increased social efficiency of input choices by the benefitted firms.

Quite apart from industrial location policy itself, this observation raises important questions about the government policies that restrict the access of small and medium size firms to bank credit. These restrictions may result in efficiency losses equal to as much as 4 percent of the land, labor, and capital costs incurred by the manufacturing sector. Certainly one must question the wisdom of such policies.

Of course it is possible that these are good reasons for the government's credit policies. But given the magnitude of the costs incurred, these reasons need careful thought. If there are good reasons for these policies, then one must ask if the objectives of those policies are misserved by the loan guarantees used in industrial location policies. The simulations do not touch upon these interactions between location policies and other objectives of the Korean government, but such interactions must be considered by policymakers who wish to make good use of our findings.

It is also important to note that if the Korean government were to alter its policy of credit rationing, subsidies to the price of labor would become the most efficient devices for relocating firms. This finding is not particularly surprising on theoretical grounds--the cost share of labor is high and that suggests relatively high efficiency. But there is some surprise since the Korean government has relied only little on subsidies of this form in its efforts to influence location choices. Indeed, wage bill subsidies appear to be more efficient than the currently popular land price subsidies favored by the government.

Less clear from the simulations is the relative merits of subsidies to fixed and variable inputs. We do find that if the marginal social costs of private fixed inputs are anywhere near their shadow values to individual firms, subsidies to fixed inputs are dominated by subsidies to variable inputs. However, most fixed inputs are public goods, or at least quasi-public goods, and the comparison of shadow value to shadow cost is not wholly appropriate for these inputs since the optimal choice of public goods depends on the sum of the shadow values across firms, not on the shadow value of one firm in isolation.

This last observation highlights one important feature of subsidies of public goods: such subsidies will be more efficient the more densely populated the area in which the investments are made. Since one aim of relocation policy is to deconcentrate economic activity, subsidies to fixed inputs are likely to be less efficient where, from a policy point of view, they are most wanted. This does not imply that fixed input subsidies cannot dominate variable input subsidies on the outskirts of the city, only that for such dominance the marginal social cost of the fixed input must be lower than it would have to be in a more densely populated area.

Before a fuller evaluation of the efficiency of fixed input subsidies can be conducted it is quite important that further research into the costs of such investments be conducted. The simulations in the previous section were sharply constrained by the absence of such cost information.

A second issue related to subsidies on fixed inputs is the relationship between firm size and publicly provided inputs. At one extreme one could view publicly provided inputs as available to all firms in a single fixed quantity. At the other extreme one could view the fixed inputs to be available in proportion to the firms' output.

The simulations reveal that literal application of the former view leads to markedly more variation in total land, labor, and capital costs as output varies than is observed in data from Korean manufacturing. Hence we lean toward the latter view under which the relative attractiveness of fixed input subsidies is independent of the level of output.

However, some publicly provided inputs are likely to fit better the first mold, and to the extent that they do, the relative benefits and efficiency of fixed input subsidies will vary with firm size. The simulations indicate that in the face of literally constant fixed inputs, the balance of efficiency tilts toward fixed input subsidies and away from variable input subsidies as the level of output rises.

We close by noting that the simulations suggest that returns to scale may be of greater interest than we initially thought. Loan guarantees alter the marginal cost of output by a factor of about two. Such large alterations of marginal cost could have considerable impact on the level of output selected by the firm even if returns to scale are fairly close to unity (as our evidence suggests). This result is confirmed in our casual surveys of Korean firms receiving such guarantees, it was not uncommon for us to find them doubling their output. The consequences of such output level effects for the overall efficiency of industrial location policy (or credit allocation policies) should be accounted for. However, since our focus is on the relative efficiencies of mechanisms yielding equal benefits to the firm, we have less concern with the differentials across policies, and the differentials in output inefficiencies are likely to be small given the observed pattern of nearly constant marginal costs.

Appendix A

A Formal Analysis of Alternative Industrial Location Policies

In this appendix I develop a formal analysis of the relative efficiencies of alternative relocation policies. The policies considered are all intended to induce the firm to choose one particular site rather than another. To be successful, each must offer the firm some level of benefits, $\bar{B}$, sufficient to make the government's preferred site as profitable as the firms's preferred location in the absence of the policy. By the relative efficiency of two policies, I mean the difference in the net social worth of the bundles produced by the firm under the two policies given that both policies are successful in yielding the firm benefits $\bar{B}$. The total inefficiency of policies would also include the social cost ($\bar{B}$ in the case of no externalities and optimal provision of public services) of not locating at the firm's most desirable location.

These analyses of the cost to government of relocating the firm are richer than the usual economist's fare. All too frequently economists point out that the cheapest way to achieve a policy goal, such as relocation, is to make a cash grant. Unfortunately, such simplistic policies are often not feasible, whatever their economic virtues. In the following I try to be more realistic by looking for optimal policies in the face of restrictions on feasible policies.

Thus, for example, I establish conditions for determining price and quantity subsidy mechanisms when firms are able to vary some inputs but must take others as fixed and the government must choose its policies from a set of politically feasible subsidy schemes.

The first analyses are limited to location policies which rely on price mechanisms. These analyses will be familiar to many readers; they are very similar to the consumer analyses found in Diamond and McFadden (1975). The analysis of price mechanisms provides a comfortable path to the less familiar analysis of non-price mechanisms which follows. Extending our analysis to embrace the non-price mechanisms will simply require replacing the unrestricted cost and profit functions suitable for studying price mechanisms with their restricted counterparts. The analyses I conduct are in the same spirit as the consumer behavior studies of Latham (1980) and Kennedy and MacMillan (1980).

To demonstrate the power of cost and profit functions for comparing policies, I shall pose and answer the following eight questions:

- If only one input price is to be subsidized, which input should be chosen if the firm must receive benefits $\bar{B}$ to be induced to choose this site?
- If several, but not necessarily all, inputs to be subsidized, what are the optimality conditions for the subsidies?

• Would it be optimal to achieve the required benefits at this site by offering the firm the prices which prevail at the alternative site? In particular, if two sites only differ in transportation costs of inputs, is it an optimal (second best) solution to offer to pay differential transport costs? Or if two sites differ in regard to only one price, should that input be subsidized rather than another?

• Are price subsidies more attractive to firms for which the deadweight loss from the subsidy would be larger?

• If only one input which is provided by government rather than bought by the firm is to be increased, which input should be chosen if the firm must receive benefits $\overline{B}$?

• If several government provided inputs are to be increased, what are the optimality conditions for these increases?

• What is the optimal mix of price and non-price mechanisms for inducing a move given that not all prices and inputs can be altered?

• When are non-price mechanisms more efficient than price mechanisms?

Now, as a prelude to the technical analysis itself, I shall establish some notational apparatus.

Let y be the output of the firm, q be a vector of privately purchased inputs, and s a vector of publicly provided inputs. Let P_y be the price out output, p be a vector of input prices for q, and r a vector of input prices for s.

$$y = f(q,s)$$

is the firm's production function

$$c = c(p,s,y)$$

is the cost function corresponding to f and

$$\pi = \pi(p_y,p,s)$$

is the profit function corresponding to f. A restricted profit function corresponding to a set of constraints of the form

$$q_i \leq \bar{q}_i \qquad\qquad i = 1,\ldots,n$$

is denoted by

$$\bar{\pi} = \bar{\pi}(p_y,p,s,\bar{q}) .$$

However, to begin with we shall ignore S and $\bar{q}$, considering only purchased inputs, their prices, and output in the long run.

Define the subsidy paid by government, S, to be the difference between the market value of the bundle of inputs chosen under the subsidy and the payments made by the firm for the inputs at subsidized prices. Denote market prices p_m and subsidized prices p.

$$(1) \qquad S = \sum_{i=1}^{n} (p_i^m - p_i) \frac{\partial C(p,y)}{\partial p_i}$$

(Recall the derivative of the cost function is the conditional demand for the input.)

Define the benefits to the firm, B, as the reduction in costs incurred due to the subsidy.

$$(2) \qquad B = C(p^m,y) - C(p,y) = \sum_{i=1}^{n} p_i^m \frac{\partial C(p^m,y)}{\partial p_i} - \sum_{i=1}^{n} p_i \frac{\partial C(p,y)}{\partial p_i} .$$

The economic loss associated with the subsidy is therefore:

$$(3) \qquad L = S-B = \sum_{i=1}^{n} p_i^m \frac{\partial C(p,y)}{\partial p_i} - \sum_{i=1}^{n} p_i^m \frac{\partial C(p^m,y)}{\partial p_i} \geq 0$$

with the inequality following from the fact that $\frac{\partial C(p_m,y)}{\partial p_i}$, $i = 1,\ldots,n$, is the cost minimizing vector of q's for $p = p_m$.

<u>One input subsidized</u>. The choice of which input to subsidize turns on two factors: the substitutability of factors one for another, and the amount of each factor in use. To see this, let us ask how inefficiency, L, varies with benefits, B, when benefits are transmitted by subsidizing one input, say q_1.

From (2) we obtain by differentiation

$$1 = -\frac{\partial C(p,y)}{\partial p_1} \cdot \frac{dp_1}{dB}$$

($C(p_m,y)$ if fixed as p_1 changes.) hence,

$$\frac{dp_i}{dB} = -\frac{1}{\frac{\partial C(p,y)}{\partial p_i}} = -\frac{1}{q_i(p,y)}$$

Differentiating (3) we obtain

$$(4) \qquad \frac{\partial L}{\partial B} = \sum_{j=1}^{n} p_j^m \frac{\partial^2 C(p,y)}{\partial p_i} \cdot \frac{dp_i}{dB} = -\frac{\sum_{j=1}^{n} p_j^m \frac{\partial q_j}{\partial P_i}}{q_i}$$

which indicates that choosing to subsidize a good used in large quantity ($q_i >> 0$) or a good which is not much of a substitute for others will reduce the inefficiency incurred , in granting benefits.

At this point I shall introduce two concepts which will appear frequently below.

α_i^{ms} is the budget share of the quantity of the i^{th} input picked at subsidized prices when evaluated at market prices:

$$\alpha_i^{ms} = \frac{p_i^m q_i\ (p,y)}{\sum_{j=1}^{n} p_j^m q_j\ (p,y)}$$

θ_i^{ms} is the elasticity of the cost inputs chosen at subsidized prices evaluated at market price:

$$\theta_i^{ms} = \frac{p_i^m}{\sum_{j=1}^{n} p_j^m q_j\ (p,y)} \cdot \frac{\partial(\Sigma p_j^m q_i\ (p,y))}{\partial p_i}$$

$$= \frac{p_i^m q^m{}_i}{\sum_{j=1}^{n} p_j^m q_j} \cdot \frac{1}{q_i^m} \cdot \sum_{i=1}^{n} p_j^m \frac{\partial q_j}{\partial p_i} .$$

Equation (4) thus becomes

$$(4') \qquad \frac{\partial L}{\partial B} = -\frac{\theta_i^{ms}}{\alpha_i^{ms}}$$

The rule of thumb for subsidy schemes which (4′) suggests is to subsidize a good which makes up a relatively large part of the firms' outlays, and which is not easily substituted for. Another way to view (4′) is that the denominator indicates that when α_i is large, only a small change in price is needed to confer a given level of benefits; the numerator indicates the extent to which any particular change in price distorts consumption.

Optimal Subsidy Schemes. Suppose the government will subsidize a given subset of inputs $q_1, \ldots, q_k$ $k < n$. What are the optimality conditions for the subsidy scheme given the requirement that firms receive benefits $\bar{B}$ from the subsidies.

We wish to minimize:

$$L = \sum_{i=1}^{n} p_i^m \frac{\partial C(p,y)}{\partial p_i} - \sum_{i=1}^{n} p_i^m \frac{\partial C(p^m,y)}{\partial p_i}$$

subject to $B = \bar{B}$.

Form the Lagrangian

$$\zeta = \Sigma p_i^m q_i - \Sigma p_i^m q_i^m + \lambda(\bar{B} - C(p^m,y) + C(p,y))$$

The first order conditions are:

$$\frac{\partial \zeta}{\partial p_i} = \sum_{j=1}^{n} p_j^m \frac{\partial q_j}{\partial p_i} - \lambda \frac{\partial C(p,y)}{\partial p_i} = 0 \qquad i = 1,\ldots,k$$

or

$$\frac{\sum_{j=1}^{n} p_j^m \frac{\partial p_j}{\partial p_i}}{q_i} = \lambda \qquad i = 1,\ldots k$$

i.e.,

i.e.

$$(5) \qquad \frac{\theta_i^{ms}}{\alpha_i^{ms}} = \frac{\theta_j^{ms}}{\alpha_j^{ms}} \qquad i,j = 1,\ldots,k$$

plus $B = \bar{B}$.

Condition (5) can also be expressed in terms of the Allen Elasticities of Substitution (AES). The AES between goods s and t, ss_t can be expressed (Blackorby, Primont, and Russell (1978)) as:

$$\sigma_{st} = \frac{C(p,y) \frac{\partial^2 C}{\partial p_s \partial p_t}}{q_s q_t}$$

thus

$$\frac{p_s^m q_s \sigma_{st}}{C(p,y)} = \frac{p_s^m \frac{\partial^2 C}{\partial p_s \partial p_t}}{q_t}$$

and

$$\frac{\sum_{s=1}^{n} \sigma_{st} p_s^m q_s}{C(p,y)} = \frac{\sum_{s=1}^{n} p_s^m \frac{\partial^2 C}{\partial p_s \partial p_t}}{q_t}$$

Consequently, condition (5) can be expressed as

$$(5') \qquad \sum_{\ell=1}^{n} \sigma_{\ell i} \alpha_\ell^{ms} = \sum_{\ell=1}^{n} \sigma_{\ell j} \alpha_\ell^{ms} \qquad i,j=1,\ldots,k$$

In general, the expression θ_i^{ms}/α_i can be replaced by $\frac{\sum_{\ell=1}^{n} s_\ell \sigma_{\ell i} \alpha_\ell^{mx}}{1-s}$ where s is the average rate of subsidy, $S/\sum_{j=1}^{n} p_j^m q_j$.

The tie of this result to the previous is obvious. One should first subsidize the input of which $\theta_i^{ms}/\alpha_i^{ms}$ is a minimum, as in the case above. When R_i^{ms}/a_i^{ms} for that input exceeds that for a second input, that second input should then be subsidized. This practice should be continued until $B = \overline{B}$.

Notice that in the special case of k = n, when all inputs can be subsidized, we find that if the quantities of goods chosen at subsidized prices are the same as at market prices (which, of course, is achieved by equiproportionate subsidies),

$$\Sigma p_j^m \frac{\partial q_j(p,y)}{\partial p_i} = \Sigma p_j^m \frac{\partial q_j(p^m,y)}{\partial p_i} = 0$$

because

$$q_i^m = \frac{\partial C\ (p^m,\ y)}{\partial p_i} = \frac{\partial \Sigma P_j^m\ q_j^m}{\partial p_i} = q_j^m + \sum_{j=1}^{n} p_j^m \frac{\partial q_j^m}{\partial p_i}$$

implying that the first order condition is met with $g = 0$.

Matching the Alternative Site. Suppose prices are p in the site most attractive to the firm. Prices in the site which the government wants selected are pm. Clearly the government can make the firm indifferent between the two sites by charging prices p at the second site also. When is this desirable? When not desirable, what changes should be made?

Let us suppose prices have been set at p, and the government now contemplates altering p_1 and p_2 keeping $B = \bar{B}$ as required. Thus,

$$\Delta B = 0 = \frac{\partial C}{\partial p_1} \cdot \Delta p_1 + \frac{\partial C}{\partial p_2}\ \Delta p_2$$

hence

$$\frac{\Delta p_2}{\Delta p_1} = - \frac{\frac{\partial C}{\partial p_1}}{\frac{\partial C}{\partial p_2}} = - \frac{q_1\ (p,y)}{q_2\ (p,y)}$$

The effect on inefficiency of these price changes is

$$\left(\frac{dL}{dp_1} \right)_B = \frac{\partial L}{\partial p_1} + \left(\frac{dp_2}{dp_1} \right)_B \cdot \frac{\partial L}{\partial p_2}$$

$$= \sum_{j=1}^{n} p_j^m \frac{\partial q_j}{\partial p_1} - \frac{q_1}{q_2} \sum_{j=1}^{n} p_j^m \frac{\partial q_j}{\partial p_2} .$$

This can be formulated as

$$\frac{1}{q_1}\left(\frac{dL}{dp_1}\right)_B = \left(\frac{p_1^m}{p_1^m}\ \frac{\Sigma p_j^m q_j}{\Sigma p_j^m q_j}\right)\frac{\Sigma p_j^m \frac{\partial q_j}{\partial p_1}}{q_1} - \left(\frac{p_2^m}{p_j^m}\ \frac{\Sigma_j p_j q_j^m}{\Sigma p_j^m q_j}\right)\frac{\Sigma p_j^m \frac{\partial q_j}{\partial p_2}}{q_2}$$

$$(6) \qquad = \frac{\theta_1^{ms}}{\alpha_1^{ms}} - \frac{\theta_2^{ms}}{\alpha_2^{ms}}$$

Thus if goods 1 and 2 meet the optimality conditions, no change in these two prices is called for. However, if the difference (6) is not zero, a more efficient device to entice the firm to come to the desired site is available. The prices at the alternative site should not be matched.

In particular, if two sites differ only in the cost of transporting inputs from their sources, it is inappropriate, in general, to induce location at the more costly site by offering to pay the differentials in transport costs.

In the same vein, and also important, if two sites differ only with regard to one input price, it is possible that the optimal subsidy scheme is to subsidize still another good.

These remarks would be trivial if we were always allowing for a first best solution, i.e., equiproportionate price subsidies, however the force of these comments comes from their applicability even in second best cases in which only one or several inputs will be subsidized.

What is Drawn to the Subsidy? The deadweight losses induced by a price subsidy scheme yielding fixed benefits are smallest for the firms which both use much of the subsidized good and find it difficult to substitute for the subsidized good. If we ask for what sort of firm will a particular price subsidy be most attractive, we find that on the one hand, the subsidy will appeal more to firms which use much of the subsidized good, but that it will also appeal more to firms that can substitute more easily for that good.

To see this, simply note that

$$\frac{\partial B}{\partial p_i} = - q_i$$

but

$$\frac{\partial^2 B}{\partial p_i^2} = - \frac{\partial q_i}{\partial p_i}.$$

Hence, firms with high q_i benefit more for each dollar of subsidy, but the marginal gains rise faster for firms whose consumption of q_i is more responsive to price. Firms for whom there is a large inframarginal benefit will be more attracted to price subsidies, which is good from an efficiency perspective. But firms ready to respond more to the subsidy at the margin will also be more attracted, which is bad for efficiency.

Allowing for Output Effects. Little is changed in the above results by allowing the firm to alter its output in response to changes in factor prices. Benefits are altered in that altered revenues may shift benefits to the firm, and changes in input use will arise from output changes as well as substitution effects. However, if one reinterprets θ_i^{ms} as the elasticity (with respect to the price of goods) of the market value of inputs net of increased revenues, evaluated at initial market prices, then all the formulae above would be repeated in an analysis based on profit functions rather than cost functions, except that total inefficiency would have to include any lost consumer's surplus.

If all inputs were purchased at set prices, with or without distortions, the above analysis would fill all our needs. However, in reality some inputs are available only in fixed quantities at any given moment. Moreover, some governments' relocation mechanisms share this character: the government provides the firm with a fixed quantity of some good at no cost, or at less than market cost. If the fixed quantities of goods do not coincide with the cost minimizing or profit maximizing amounts, then actual costs or profits will diverge from those which would be calculated from unrestricted cost for profit functions. If government is providing an input to the firm, the firm's choices may also be distorted, although underprovision by government can sometimes be overcome by private purchases to supplement the government's provisions.

I shall now introduce the apparatus of restricted cost functions which will enable us to incorporate analyses of non-price relocation mechanisms into our general framework. The adaptation of the foregoing results on price-mechanisms to include quantity restrictions will be clear from our discussion, so we will not repeat all of those manipulations. Similarly, the extension of these results to profit functions from cost functions is straightforward, and I won't go into details.

It is worth noting that two common location policies, prohibitions and mandates, are not treated in this section. These policies do not alter the relative input prices in the target site, nor do they require increases in the provision of publicly provided goods. Consequently, they induce no misallocation of resources except for their possible effect on optimal location per se.

The primary purpose of the following development is to establish that adaptations of the notions of cost or profit functions will permit one to analyze non-price relocation mechanisms as well as price mechanisms. The approach taken to the firm here is similar to that taken to the consumer by Latham (1980) and Kennedy and MacMillan (1980).

First let us consider a policy which provides a firm with a fixed amount of the n^{th} input, $\bar{q}_n$, at a cost

$C_n < p_n\bar{q}_n$. If

$$\bar{q}_n < \frac{\partial C(p,y)}{\partial p_n}$$

then the firm will accept the offer and augment the quantity $\bar{q}_n$ exceeds the firm's planned use of q_n, then it will accept the offer if costs would be lower by using $\bar{q}_n$ at cost C_n than otherwise, i.e., if

$$C(p,y,\bar{q}) < C(p,y)$$

where $C(p,y,\bar{q})$ denotes the cheapest way to produce y given that prices are p and that one uses $\bar{q}$ obtained at cost C_n.

It is of interest to allow the government to jointly offer $\bar{q}_n$ and alter other input prices, in which case the benefits to the firm from a policy are

$$B = C(p_m,y) - C(p,y,\bar{q}) \ .$$

The subsidy to the firm from such a policy would be

$$S = \sum_{i=1}^{n} p_i^m q_i^s - C(p,y,\bar{q})$$

where $q_1^s,\ldots,q_{n-1}^s$ are the quantities the firm would choose if $q_1,\ldots,p_{n-1}$ given q and $\bar{q}_n$.

Holding C_n fixed

$$C(p,y,\bar{q}_n) < C(p,y,\bar{q}_{n2}) \text{ if } \bar{q}_{n1} > \bar{q}_{n2}$$

Furthermore

$$v_n = -\frac{\partial C(p,y,\bar{q}_n)}{\partial \bar{q}_n} \leq p_n$$

if $\bar{q}_n > \delta C(py)/\delta p_n$ since otherwise it would pay the firm to purchase $\bar{q}_n$ without constraint. Also

$$\frac{\partial^2 C(p,y,\bar{q}_n)}{\partial^2 \bar{q}_n} \leq 0$$

as it becomes increasingly difficult to substitute $\bar{q}_n$ for other inputs as q_n rises.

A striking result is that the derivatives of the restricted cost function with respect to factor prices still yield input demands, although now they are restricted demands conditioned on $q_n = \bar{q}_n$. To see this, let q* minimize the cost of producing y at p = p* given $q_n = \bar{q}_n$. Then

$$g(p) = C(p,y,\bar{q}_n) - \sum_{i=1}^{n-1} p_i q_i^* - C_n \leq 0$$

reaches a maximum at p = p* and that implies

$$\frac{\partial g(p)}{\partial p_i} = \frac{\partial C(p,y,\bar{q}_n)}{\partial p_i} - q_i^* = 0 .$$

so

$$q_i^* = x_i\,(p,y,\bar{q}_n) = \frac{\partial C(p,y,\bar{q}_n)}{\partial p_i}$$

(Let $q_n^s = \bar{q}_n$).

As with price mechanisms, non-price mechanisms generally bring deadweight losses.

$$L = S - B = \sum_{i=1}^{n} p_i^m q_i^s - \sum_{i=1}^{n} p_i^m q_i^m \geq 0$$

Now we can ask as before how deadweight loss changes with benefits, but here the benefits are altered by increasing $\bar{x}_n$ (holding C_n fixed).

$$\frac{\partial B}{\partial B} = 1 = -\frac{\partial C(p,y,\bar{q}_n)}{\partial \bar{q}_n} \cdot \frac{\partial \bar{q}_n}{\partial B}$$

$$\frac{\partial \bar{q}_n}{\partial B} = \frac{-1}{\partial C(p,y,\bar{q}_n)/\partial \bar{q}_n} = \frac{1}{v_n}$$

$$\text{(6)} \qquad \frac{dL}{dB} = \sum_{i=1}^{n} p_i^m \frac{\partial q_i^s}{\partial \bar{x}_n} \cdot \frac{\partial \bar{q}_n}{\partial B} = \frac{\sum_{i=1}^{n} p_i^m \frac{\partial q_i^s}{\partial \bar{q}_n}}{v_n}$$

The intuition of this result is straightforward. First, if the shadow price of $\bar{q}_n$, $\bar{v}_n$, is low, a larger increase in $\bar{q}_n$ is needed to achieve a given increase in benefits. Second, a given increase in $\bar{g}_n$ can substitute for other inputs.

This relationship reflects a much more general result, just as equation (4) reflected more general optimality conditions. Consider a set of relocation mechanisms which alter the prices of some inputs and provide amounts of others which exceed what the firm itself would choose. Let $p_1,\ldots,p_n$ denote the prices of goods, $q_1,\ldots,q_k$ which the firm buys in the market price, perhaps at distorted prices. Let $q_{k+1},\ldots,q_n$ denote a vector of goods provided by the government for a set cost C_n. We shall now ascertain a set of optimality conditions for these mechanisms given benefits must equal some set level B.

The problem, then is to minimize

$$L = \sum_{i=1}^{n} p_i^m q_i^s - \sum_{i=1}^{n} p_i^m q_i^m$$

where $q_1^s,\ldots,q_n^s$ are the cost minimizing input choices given $p_1,\ldots,p_k$, y, and $\bar{q}_{k+1},\ldots,\bar{q}_n$. Also $q_j^s = \bar{q}_j$, $j = k+1,\ldots,n$. The constraint is that

$$\bar{B} = C(p^m,y^m) - C(p_1,\ldots,p_k, y, \bar{q}_{k+1},\ldots,\bar{q}_n)$$

$$= C(p^m,y^m) - C^s$$

From

$$\zeta = L + \lambda(\bar{B} - B)$$

which yields the following first order conditions

$$(7) \qquad \sum_{j=1}^{k} p_j^m \frac{\partial q_j^s}{\partial p_i} - \lambda\frac{\partial C^s}{\partial p_i} = 0 \qquad i = 1,\ldots,k$$

$$(8) \qquad \sum_{j=1}^{k} p_j^m \frac{\partial q_j^s}{\partial \bar{q}_i} + p_i - \lambda\frac{\partial C^s}{\partial q_i} = 0 \qquad i = k+1,\ldots,n$$

$$\bar{B} = B$$

Conditions (7) are simply the optimality conditions for price mechanisms obtained above with restricted input demands replacing unrestricted input demands. Conditions (8) indicate that dL/dB (see eq. 6) must be the same for each quantity $\bar{q}_{k+1},\ldots,\bar{q}_n$, and must equal dL/dB for each price as well.

Reflection upon the optimality conditions for price mechanisms vis-a-vis those for non-price mechanisms exposes a striking difference. Equation (4) indicates that if p_i is manipulated:

$$\frac{dL}{dB} = - \frac{\Sigma p_j^m \cdot \frac{\partial q_j}{\partial p_i}}{q_i}$$

while equation (6) says that if q_i is manipulated:

$$\frac{dL}{dB} = - \frac{\Sigma p_j^m \frac{\partial q_j}{\partial q_i}}{v_i}$$

From an initial market solution, it will be more efficient to apply a non-price subsidy to a good when that good has a high shadow price, is used in small quantity, and is easily substitutable for other goods. Price mechanisms will be more efficient when the shadow price of the good is low, the good is used in large quantity, and the good is not easily substitutable for others.

The optimality conditions for non-price mechanisms have analogous implications for non-price relocation mechanisms as were drawn earlier for price mechanisms. They firmly establish the power of the restricted cost function (and with simple adaptation, the restricted profit function) for analyzing how relocation policies alter firms' allocative efficiency.

Appendix B

Parameterizing The Translog Restricted Cost Function Using User Provided Elasticities and Factor Shares

We now discuss how the simulation model converts user supplied data on (i) elasticities of substitution, (ii) demand elasticities of variable inputs with respect to fixed inputs, and (iii) factor shares, into parameters for the translog restricted cost function.

The first step is to declare the initial conditions for the model. These include the levels of output and fixed inputs, the variable factor prices, and the level of total cost for which the user-provided elasticities and factor shares are presumed to hold.

There are two important cases to be considered. In the first, the technological data from other sources are assumed to be estimated under the same restrictions that apply to the translog restricted cost function. For example, if only publicly provided inputs are being held fixed, it seems reasonable to assume that these conditions correspond to the conditions under which most elasticities of substitution among capital and labor have been estimated (i.e., with fixed levels of publicly provided inputs).

The second case is that in which the simulation model is holding fixed a quantity that was allowed to vary in the empirical studies. Perhaps we wish to simulate a fixed-quantity capital subsidy; how can we adapt to our needs elasticity of substitution estimates from studies in which capital was varying freely?

In the first case, if the available estimates of the elasticity of substitution are conditional on fixed levels of some inputs, such as publicly provided inputs, then the formula given above for the elasticity of substitution in terms of the cost function still applies, but the appropriate cost function is the restricted cost function.

$$\sigma_{ij} = \frac{v \dfrac{\partial^2 v}{\partial P_i \partial P_j}}{q_i q_j} \qquad i,j=1,\ldots,k \qquad i \neq j$$

Equations (2) above can be rewritten as

$$\frac{\partial v}{\partial P_i} = \frac{v}{P_i} (a_i + \sum_{j=1}^{k} \alpha_{ij} \ln P_j + \sum_{j=k+1}^{n} \gamma_{ij} \ln q_j + \tau_i \ln y) = \frac{v}{P_i} (S_i)$$

Thus it follows that

$$\frac{\partial^2 v}{\partial P_i \partial P_j} = \frac{v}{P_i P_j} \alpha_{ij} + \frac{S_i}{P_i} \frac{v}{P_j} \cdot S_j$$

Consequently, for the translog restricted cost function, we obtain

$$\sigma_{ij} = \frac{\alpha_{ij}}{S_i S_j} + 1$$

or

$$\alpha_{ij} = (\sigma_{ij} - 1) S_i S_j \qquad i,j=1,\ldots,k \quad i \neq j$$

Thus, the elasticities of substitution, coupled with equation (8), allow us to fix all the γ_{ij} once initial variable factor shares are specified.

Values for the γ_{ij} are determined through knowledge of the elasticities of demand for the variable inputs with respect to the fixed inputs.

$$q_i = \frac{\partial v}{\partial P_i} = \frac{v}{P_i} (S_i) \qquad i=1,\ldots,k$$

therefore,

$$\frac{\partial q_i}{\partial q_j} = \frac{v}{P_i q_j} \gamma_{ij} - \frac{S_i}{P_i} \cdot \frac{v}{q_j} S^*_j \qquad i = 1,\ldots,k \quad j = k+1,\ldots,n$$

or

$$\varepsilon_{ij} = \frac{q_j}{q_i} \frac{\partial q_i}{\partial q_j} = \frac{\gamma_{ij}}{S_i} - S^*_j$$

so that

$$\gamma_{ij} = (\varepsilon_{ij} + S^*_j) S_i$$

The elasticities ε_{ij} used in the simulations reported in chapter IV are drawn from the econometric work reported in chapter III, and the initial shares of the variable inputs, S_i, used are those that we observed in Korea. The computer program will accept any ε_{ij} and S_i provided by the user. The shadow shares of the fixed inputs pose a more subtle problem because only the initial quantities of the fixed inputs are observed; we are in the dark about their shadow prices. Fortunately, we can indirectly retrieve the shadow shares of the fixed inputs from other variables.

The shadow value of the j^{th} fixed input is simply the savings in other inputs that access to one more unit of that fixed input would yield. That is,

$$w_j = - \sum_{j=1}^{k} \frac{\partial q_i}{\partial q_j} \cdot P_j \qquad j=k+1,\ldots,n$$

so that

$$w_j q_j = - \sum_{k=1}^{k} \frac{q_i q_j}{q_i} \frac{\partial q_i}{\partial q_j} P_i$$

or

$$w_j q_j = - \sum_{i=1}^{k} P_i q_i \, \varepsilon_{ij}$$

so that

$$s^*_j = \frac{w_j q_j}{v} = - \sum_{j=1}^{k} S_i \, \varepsilon_{ij} \qquad j=k+1,\ldots,n$$

Hence, the γ_{ij} can be fixed by computing

$$\gamma_{ij} = (\varepsilon_{ij} - \sum_{\ell=1}^{k} S_{\ell}\, \varepsilon_{\ell j}) S_i \qquad i=1,\ldots,n \quad j=k+1,\ldots,n$$

These numbers, coupled with equation (7) then provide values for the τ_i as well.

With τ_i, γ_{ij}, and α_{ij} all in hand, initial variable prices and shares for the variable inputs, initial fixed input quantities and initial output level permit us to calculate the a_i using equations (2).

The only remaining parameters in the model are the h_i, the B_{ij}, and the θ_i. Once the B_{ij} are determined, equation (9) dictates the $_i$. With the θ_i and B_{ij}, the formula above for the S^*_i, coupled with equations (3), yield values for the h_i.

Because of the limited information available to us regarding fixed inputs, the values of the B_{ij} in the simulation model had to be set arbitrarily. We chose to assume values consistent with the following conjectures: had firms been allowed to vary the fixed inputs at a marginal price equal to the shadow price, then (i) the own price elasticities of demand for the fixed inputs would be unitary and (ii) the cross price elasticities among the fixed inputs would be zero.

The first conjecture has little impact on our analyses since cross price elasticities are much more important in determining deadweight loss and benefits than are own price elasticities. The second conjecture has little impact because we seldom consider two fixed inputs in our analyses (so there is usually no cross price effect needed in the models) and also because deadweight losses are driven more by cross effects between fixed and variable inputs or among variable inputs than between fixed inputs.

The link between B_{ij} and the "as if" demand elasticities will be clearer as we now develop parameterization of the translog restricted cost function in the second case (in which we consider fixing an input that is variable in the available econometric studies).

For analytical tractability in this second case, we abstract from other fixed inputs. Thus, we find ourselves considering the relationship between an unrestricted cost function and its restricted counterpart in which one input is fixed.

The available econometric evidence pertains to an unrestricted cost function

$$C = c(P_1, \ldots, P_K, y)$$

I assume that the k^{th} input is to be fixed and use $P = (p_1, \ldots, p_{k-1})$ as needed. Since the elasticity of substitution and factor share information available to us pertain to this unrestricted cost function and its derivatives, we wish to explore the link between this set of equations and the restricted cost function $v(P, q_k, y)$ and its derivatives. The link is forged by noting that if p_k were equal to the shadow price of q_k at the fixed level in question (w_k) the firm, if left unrestricted, would choose to purchase just the restricted quantity q_k.

Consequently we find

$$H = c(P, w_k, y) = v(P, q_k, y) + w_k q_k$$

where the last term on the right reflects the fact that the restricted cost function only yields variable costs. The point is that for given p, if $p_k = w_k$, it doesn't matter whether the firm is restricted or not, because factor choices would be the same in either event.

It is very useful to explore some of the derivatives of H. (Throughout keep in mind that $w_k = -\partial v/\partial q_k$.)

$$\frac{\partial H}{\partial q_k} = \frac{\partial c(p, w_K, y)}{\partial q_K} = - \frac{\partial c}{\partial p_K} \cdot \frac{\partial^2 v}{\partial q^2_K}$$

<u>and</u>

$$\frac{\partial H}{\partial q_K} = \frac{\partial [v(p, q_K, y) + w_K q_K]}{\partial q_K} = - \frac{\partial^2 v}{\partial q_K} \cdot q_K$$

which confirms that

$$\frac{\partial c}{\partial P_K} = q_K$$

Similarly

$$\frac{\partial^2 H}{\partial q_K^2} = \frac{\partial^2 c}{\partial P_K^2}\left[\frac{\partial^2 v}{\partial q_K^2}\right]^2 - \frac{\partial c}{\partial P_K} \cdot \frac{\partial^3 v}{\partial q_K^3} = \frac{\partial^2 c}{\partial P_K^2}\left(\frac{\partial^2 v}{\partial q_K^2}\right) - q_K \frac{\partial^3 v}{\partial q_K^3}$$

and

$$\frac{\partial^2 H}{\partial q_K^2} = - \frac{\partial^3 v}{\partial q_K^3} \cdot q_K - \frac{\partial^2 v}{\partial q_K^2}$$

Thus

$$(11) \quad \frac{\partial^2 c}{\partial P_K^2} = \frac{-1}{\frac{\partial^2 v}{\partial q_K^2}}$$

when the left hand side is evaluated at (p, w_k, y). Stated alternatively

$$\frac{\partial q_K}{\partial p_K} = \frac{1}{\frac{\partial w_K}{\partial q_K}}$$

when the left hand side is evaluated at (p, w_k, y), a result that should come as no surprise.

Next consider

$$\frac{\partial H}{\partial P_i} = \frac{\partial c}{\partial P_i} - \frac{\partial c}{\partial P_K} \cdot \frac{\partial^2 v}{\partial q_K \partial P_i}$$

so that

$$\frac{\partial^2 H}{\partial P_i \partial q_K} = - \frac{\partial^2 c}{\partial P_i \partial P_K} \cdot \frac{\partial^2 v}{\partial q_K^2} - \frac{\partial c}{\partial P_K} \cdot \frac{\partial^3 v}{\partial q_K^2 \partial P_i} + \frac{\partial^2 c}{\partial P_K^2} \cdot \frac{\partial^2 v}{\partial q_K^2} \; \frac{\partial^2 v}{\partial q_K \partial P_i}$$

But by (11)

$$\frac{\partial^2 c}{\partial P_K^2} \cdot \frac{\partial v}{\partial q_K^2} = -1$$

so

$$\frac{\partial^2 H}{\partial P_i \partial q_K} = - \frac{\partial^2 c}{\partial P_i \partial P_K} \cdot \frac{\partial^2 v}{\partial q_K^2} - \frac{\partial c}{\partial P_K} \cdot \frac{\partial^3 v}{\partial q_K^2 \partial P_i} - \frac{\partial^2 v}{\partial q_K \partial P_i}$$

But using the alternative form of H, we obtain

$$\frac{\partial^2 H}{\partial P_i \partial q_K} = - \frac{\partial^3 v}{\partial q_K^2 \partial P_i} \cdot q_K$$

Hence

$$(12) \quad \frac{\partial^2 c}{\partial P_i \partial P_K} = - \frac{\dfrac{\partial^2 v}{\partial q_K \partial P_i}}{\dfrac{\partial^2 v}{\partial q_K^2}}$$

Next consider

(13) $$\frac{\partial H}{\partial P_i} = \frac{\partial c}{\partial P_i} - \frac{\partial c}{\partial P_K} \cdot \frac{\partial^2 v}{\partial q_K \partial P_i}$$

so that

$$\frac{\partial^2 H}{\partial P_i^2} = \frac{\partial^2 c}{\partial P_i^2} - \frac{\partial^2 c}{\partial P_i \partial P_K} \cdot \frac{\partial^2 v}{\partial q_K \partial P_i}$$

$$- [\frac{\partial^2 c}{\partial P_K \partial P_i} - \frac{\partial^2 c}{\partial P_K^2} \cdot \frac{\partial^2 v}{\partial q_K \partial P_i}] \frac{\partial^2 v}{\partial q_K \partial P_i}$$

$$- \frac{\partial c}{\partial P_K} \cdot \frac{\partial^3 v}{\partial q_K \partial P_i^2}$$

$$= \frac{\partial^2 c}{\partial P_i^2} - 2 \frac{\partial^2 c}{\partial P_i \partial P_K} \cdot \frac{\partial^2 v}{\partial q_K \partial P_i} + \frac{\partial^2 c}{\partial P_K^2} (\frac{\partial^2 v}{\partial q_K \partial P_i})^2$$

$$- q_K \frac{\partial^3 v}{\partial q_K \partial P_i^2}$$

Using equations (10) and (12) we obtain

$$\frac{\partial^2 H}{\partial P_i^2} = \frac{\partial^2 c}{\partial P_i^2} + \frac{2(\frac{\partial^2 v}{\partial q_K \partial P_i})^2}{\frac{\partial^2 v}{\partial P_K^2}} - \frac{(\frac{\partial^2 v}{\partial P_K \partial P_i})^2}{\frac{\partial^2 v}{\partial P_K^2}} - q_K \frac{\partial^3 v}{\partial q_K \partial P_i^2}$$

$$= \frac{\partial^2 c}{\partial P_i^2} + \frac{(\frac{\partial^2 v}{\partial q_K \partial P_i})^2}{\frac{\partial^2 v}{\partial q_K^2}} - q_K \frac{\partial^3 v}{\partial q_K \partial P_i^2}$$

But once again, the alternative form of H yields another version

$$\frac{\partial^2 H}{\partial P_i^2} = \frac{\partial^2 v}{\partial P_i^2} - \frac{\partial^3 v}{\partial P_i^2 \partial q_K} q_K$$

so

$$(14)\quad \frac{\partial^2 c}{\partial P_i^2} = \frac{\partial^3 v}{\partial P_i^2} - \frac{\left(\frac{\partial^2 v}{\partial q_K \partial P_i}\right)^2}{\frac{\partial^2 v}{\partial q_K^2}}$$

Returning to (13) and obtaining cross partials we find:

$$\frac{\partial^2 H}{\partial P_i \partial P_j} = \frac{\partial^2 c}{\partial P_i \partial P_j} - \frac{\partial^2 c}{\partial P_i \partial P_K} \cdot \frac{\partial^2 v}{\partial q_K \partial P_j}$$

$$- \left[\frac{\partial^2 c}{\partial P_K \partial P_j} - \frac{\partial^2 c}{\partial P_K^2} \cdot \frac{\partial^2 v}{\partial q_K \partial P_j}\right] \frac{\partial^2 v}{\partial q_K \partial P_i}$$

$$- \frac{\partial^2 c}{\partial P_K} \cdot \frac{\partial^3 v}{\partial q_K \partial P_i \partial P_j}$$

$$= \frac{\partial^2 c}{\partial P_i \partial P_j} + \frac{\frac{\partial^2 v}{\partial q_K \partial P_i}}{\frac{\partial^2 v}{\partial P_K^2}} \cdot \frac{\partial^2 v}{\partial q_K \partial P_j} + \frac{\frac{\partial^2 v}{\partial q_K \partial P_j}}{\frac{\partial^2 v}{\partial q_K^2}} \cdot \frac{\partial^2 v}{\partial q_K \partial P_i}$$

$$- \frac{\frac{\partial^2 v}{\partial q_K \partial P_j} \cdot \frac{\partial^2 v}{\partial q_K \partial P_i}}{\frac{\partial^2 v}{\partial q_K^2}} - q_K \frac{\partial^3 v}{\partial q_K \partial P_i \partial P_j}$$

$$= \frac{\partial^2 c}{\partial P_i \partial P_j} + \frac{\frac{\partial^2 v}{\partial q_K \partial P_i} \cdot \frac{\partial^2 v}{\partial q_K \partial P_j}}{\frac{\partial^2 v}{\partial q_K^2}} - q_K \frac{\partial^3 v}{\partial q_K \partial P_i \partial P_j}$$

But the alternative form of H yields

$$\frac{\partial^2 H}{\partial P_i \partial P_j} = \frac{\partial^2 v}{\partial P_i \partial P_j} - \frac{\partial^3 v}{\partial q_K \partial P_i \partial P_j} \quad q_K$$

So we find

$$(15) \quad \frac{\partial^2 c}{\partial P_i \partial P_j} = \frac{\partial^2 v}{\partial P_i \partial P_j} - \frac{\dfrac{\partial^2 v}{\partial q_K \partial P_i} \quad \dfrac{\partial^2 v}{\partial q_K \partial P_i}}{\dfrac{\partial^2 v}{\partial q_K{}^2}}$$

Taken together, equations (11), (12), (14), and (15) permit strikingly simple characterizations of the links between the unrestricted and restricted cost functions. We obtain

$$(16a) \quad \frac{\partial^2 c}{\partial P_i \partial P_K} = \frac{\partial^2 v}{\partial q_K \partial P_i} \cdot \frac{\partial^2 c}{\partial P_K{}^2}$$

or

$$(16b) \quad \frac{\varepsilon^u{}_{iK}}{\varepsilon^u{}_{KK}} = \varepsilon^r{}_{iK} \qquad\qquad i=1,\ldots,K-1$$

where the terms on the left side are unrestricted price elasticities with respect to p_K, evaluated at (p, w_K, y) and the right hand side is the restricted demand elasticity for q_i with respect to q_k. And for elasticities of substitution in the restricted technology, σ^r_{ij}, we obtain:

$$(17) \quad (1+S^*_K)\sigma^r_{ij} = \sigma^u_{ij} - \frac{\sigma^u_{iK}\sigma^u_{jK}}{\sigma^u_{KK}} \qquad i,j=1,\ldots,K-1 \quad i \neq j$$

where σ^r_{ij} are the unrestricted elasticities of substitution.

And for the effect of q_k on w_k we obtain:

$$(18) \quad \varepsilon^r_{KK} = - \frac{1}{\varepsilon^u_{KK}}$$

where the term on the left is the elasticity of the shadow price with respect to q_k and the term on the right is the unrestricted own price elasticity for q_k.

One might guess that since the own and cross unrestricted demand elasticities are related by

$$(19) \quad \sum_{i=1}^{k} \rho_i \varepsilon^u_{ik} = 0$$

where ρ_i is the unrestricted share of the i^{th} input, the value of ε^r_{kk} is determined through (16b) and (18) once the ε^r_{ik} are set. However, this proves not to be the case. What (19) does imply is the finding above that the shadow share of q_k can be expressed in terms of the ε^r_{ik} and the shares of the variable inputs.

Application of (18) to the specific case of the translog restricted cost function yields

$$B_{kk} = \frac{-S_k}{\varepsilon_{KK}} - (1+S_k)S_k$$

Thus the assumption of a unitary own price elasticity of unrestricted demand at the shadow price yields

$$B_{kk} = - S_k^2$$

which is what we use in the simulations for all publicly provided fixed inputs since we have not alternative information.

More generally, equations (16) - (18) have permitted us to "translate" unrestricted elasticities of substitution or demand into appropriate restricted elasticities that permit us to parameterize a restricted translog cost function using the transformed elasticities in the manner described earlier in this section.

One important activity carried out by the simulation model is to render convex the technology underlying the translog cost function. An unfortunate shortcoming of the translog specification is that for goods that have an elasticity of substitution less than one, the isoquants implied by the cost structure have concave segments. This is illustrated in Figure 1 by the solid line QQ. These segments are inconsistent with interior solutions to the cost minimization problem. Rather than cast aside the very useful translog function altogether, the simulation model adapts the model by, in effect, forcing the isoquants to become vertical or horizontal and remain so rather than become concave. This is illustrated with the dashed lines in Figure 1.

This convexification of the isoquants underlying the cost function simply reflects an intuitively appealing idea: in the real world, the substitution relationship that is most likely to give rise to negative elasticities of substitution (when we approximate the technology with a translog cost function) is indeed a zero elasticity of substitution.

APPENDIX C

This appendix presents simulation results to supplement those reported in the text. The first set offered focus on land prices and firms' costs in an effort to lend credence to our use of distance from the center of the city as a measure of publicly provided inputs. The second set of simulations explore the relationship between restricted and unrestricted translog cost function specifications.

Simulations and Spatial Structure

The first simulation results we report in this appendix pertain to the spatial structure of the Seoul region. We use the inverse of the firm's distance from the city center as a measure of fixed "non-purchased" inputs available to the firm. The mean distance in our sample is about 3 kilometers so we use .333 as the base value of fixed inputs in specifying the simulation model.

When non-purchased inputs are raised to 2.0 (1/2 kilometer from the city center), costs generally decline from fifteen to twenty-five percent with a mean of about twenty-five percent. When these inputs are cut to .125 (8 kilometers from the city center), costs generally rise from ten to twenty percent. (The "other" industry category is the one outlier in these findings, due, we think, to the relatively high demand elasticities obtained for this industry (see Table C1); this result is probably specious, arising from misspecifications in lumping all "other" manufacturing industries in one category.)

TABLE C1

AVERAGE FIRM COSTS FOR ALTERNATIVE FIXED INPUT LEVELS WITH AND WITHOUT ACCOMPANYING LAND PRICE CHANGES

Fixed input level	2.0	1.0	.333	.20	.125
Cost w land price change fixed at .222	146	136	115	105	102
Cost w land price changing*	119 (1.85)	124 (.555)	115 (.222)	116 (.111)	112 (.037)

* Figure in parentheses is assumed price of land

Table C2 reports the mean change in costs from a base cost of about 115 when fixed inputs are .333 for each of four alternative levels of fixed inputs. Below these changes are reported the net changes in costs which would occur if the altered levels of fixed inputs (distances) were accompanied by changes in land prices comparable to those observed at those distances in the Seoul region. As can be seen from the table, the land price gradient very nearly neutralizes the fixed input advantages or disadvantages of alternative locations.

This relatively good conformity of our simulation results (except for the outlier "other industries") encourages us that our parameterization of the industries is reasonably good, at least for the typical size firms for which these results are derived. (The problems associated with firms of other sizes are discussed below.) However, the good fit of our simulations does raise some concern about the appropriateness of using elasticities with respect to distance as a proxy for elasticities with respect to publicly provided inputs, even if the two are highly correlated.

Greater distance from the city center does not bring just lower publicly provided inputs; other problems also arise, most particularly increased transportation costs. Consequently, elasticities with respect to distance are probably an upper bound on the magnitude of the elasticities with respect to publicly provided inputs. In the above

TABLE C2

RESTRICTED AND UNRESTRICTED ELASTICITIES FOR THE FOOD INDUSTRY

Unrestricted

Elasticities of Substitution

	LAND/LABOR	LAND/CAPITAL	CAPITAL/LABOR
	.25	.75	.85
Shares	(.15)	(.45)	(.40)

Restricted

	Elasticity of Substitution		**Elasticity of Variable Input Demand**
	LAND/LABOR	LAND WITH CAPITAL	LABOR WITH CAPITAL
	.75	.23	.77
Shares	(.25)	(.75)	(.67)

application, it is the relationship between the price gradient and the total effects of altered distance that interests us, so there is no difficulty. But in the analyses in chapter IV, the interpretation desired is that of publicly provided input's effects on costs; consequently, in that chapter we examine simulations using reduced magnitudes for the elasticities of variable inputs with respect to the fixed input.

Simulations and Duality

The last simulation we report demonstrates the dual nature of price and quantity subsidies and supports the flipping back and forth between restricted and unrestricted specifications in implementing the simulation model. For each quantity subsidy government can make, there is a corresponding price subsidy that yields the firm the same benefits and generates the same deadweight loss. For this example, we focus on only one industry -- the Food group. Table 18 shows the specifications of elasticities for both an unrestricted and a restricted cost function for a firm receiving either price or quantity subsidies for capital when land and labor are the other two inputs.

Using prices for land and labor that reflect those paid by a typical firm, and choosing a firm with combined land and labor costs of 100 million won, we find that initial capital holdings are 6.7 units with a shadow value of 9.5 million won per unit which is, roughly, the cost of capital for a typical firm that is paying the bank rate for credit.

Using the restricted technology, offering the firm 1.1 additional units of capital reduces labor and land costs by 10 million won as the firm contracts its usage of those factors. The subsidized shadow price for land concomitantly drops to 7.98 million won per unit.

Using the unrestricted specification of the technology we find that a subsidized price for capital of 7.98 million won per units yields the firm 10.56 million won on 163 million won of total land, labor, and capital costs. Of these benefits, .13 million result from lower capital costs and 10.43 from lower land and labor costs.

The difference between the 10 million and 10.43 million won benefits in the two simulations arises from two sources. First, the computations of elasticities were rounded, so the restricted and unrestricted elasticities do not correspond exactly. Second, the translog functional forms for the unrestricted and restricted cost functions are not duals to one another; consequently, the cost structures will not, in general, coincide exactly over any finite range, even if their implicit elasticities match up properly at some point, as here. However, a discrepancy of four percent between the specifications in this case suggest that moving back and forth between the restricted and unrestricted forms is tolerable as long as one makes the adjustments to elasticities described in the theoretical section above.

APPENDIX D

Fortran Simulation Code and Program Documentation

The Fortran simulation program developed for this research can be used in either interactive or batch mode. However, the program was designed especially for interactive use so the batch input mode requires input records that correspond to what would be called for by the program in the interactive mode. The inputs will depend on which options offered by the program the user wishes to use.

The program begins by prompting the user for the number of variable inputs and the number of fixed inputs. The maximum permitted for the former is 5, for the latter 2. These numbers are entered as zero followed by the number of variable inputs, immediately followed by zero and the number of fixed inputs.

The second prompt asks the user to input the initial quantity of output, and reminds the user that unless otherwise directed, the user is to input all information with a decimal point.

The program next prompts the user for the factor prices and factor shares of the variable inputs, the quantity and social price of the fixed input, and initial total variable costs. Thereafter the user is asked to input the elasticity of substitution for each variable input pair and the elasticity of each variable input demand with respect to each fixed input.

At this point, the program calculates the parameters of the translog restricted cost function and starts an iterative loop in which the user can conduct simulations using the initial or alternative technologies.

The loop begins by asking the user whether a simulation is to be conducted under the initial conditions or altered conditions, or if the user is finished. If the user wants to alter the initial conditions, there is an option for complete reentry of initial conditions and another for only partial alterations in the initial conditions.

If a simulation is desired, the user is offered three options for setting the benefits to be received by the firm from the subsidy scheme. First, the benefits may be declared by the users. Second, the user can permit the benefits to be determined by providing the program with a specific subsidy scheme for analysis; such a subsidy scheme can alter any number of variable input prices or fixed input quantities. Third, the user can select the benefit level used in the immediately preceding simulation if the current simulation is not the first.

If the user chooses to declare the benefit level directly, the program asks the user which <u>one</u> variable input price or fixed input quantity is to be altered to yield the benefits. If the user chooses to provide a subsidy scheme that implicitly determines benefits, the program asks the user to input the subsidized levels of variable input prices and fixed input quantities.

At this point, the program calculates benefits of subsidy levels, subsidized factor uses and shadow prices, deadweight losses, and a variety of measures of possible interest to the analyst. These outputs are then written out by the program.

Next, the program returns to the top of the loop by querying the user whether or not another simulation is desired.

The inputs to the program are read from logic file number 5. The prompts are written on logical unit 6. The program output is written on logical unit 4. By anticipating what input the program will ask for, and in what order, the user can use cards or card images on a disk or tape to input the needed data in batch mode; the data will be read from logical file5. In interactive mode, the console output file should be assigned logical file 5.

```
C
C             LOCATION POLICY SIMULATION MODEL
C                    SEPTEMBER 1983
C          STORED AS MPM FORTRAN IN PHZIA ACCOUNT
C                    BACKUP IN FTN M
C                  AS OF 21:50 11/04/83
C          DEBUG M CONTAINS DEBUGGING ROUTINES
C
      COMMON/QUANT/Q
      JSTRNM=0
 888  JSTRNM=JSTRNM+1
      CALL VARNUM(JSTRNM,NV,NF)
      CALL INIT
      CALL INPUT(NV,NF)
      CALL SETPAR(NV,NF)
C     CALL CHECK(NV,NF)
      CALL BSCVAL(NV,NF)
      CALL WRBSVL(NV,NF)
      DO  100 ISMNM=1,100
      CALL SMSTR(LPTION,ISMNM,JSTRNM,NV,NF)
      IF(LPTION.EQ.0)GO TO 999
      IF(LPTION.EQ.2)GO TO 888
      WRITE(4,7)ISMNM,JSTRNM
  7   FORMAT(1H ,/,/,/,/,/,1H ,'          SIMULATION NUMBER',I3,1X,
     1                 '; COST STRUCTURE NUMBER',I3)
      CALL TOL
      CALL BENSET(ISMNM,NV,NF,JNEGSH)
      IF(JNEGSH.EQ.1)GO TO 99
      CALL DWLC(NV,NF)
      CALL PQCHGS(ISMNM,NV,NF)
C     CALL CHECK2
  99  CONTINUE
 100  CONTINUE
 999  CONTINUE
      STOP
      END

      SUBROUTINE VARNUM(J,NV,NF)
      WRITE(4,3)J
  3   FORMAT(1H ,/,/,/,/,1H ,
     1 '                   COST STRUCTURE NUMBER',I3,1X,'FOLLOWS.')
      WRITE(6,1)
  1   FORMAT(1H ,/,/,/,/,/,/1H ,'INPUT NUMBER OF VARIABLE INPUTS AS "0#"',
     1        /,1H ,'INPUT NUMBER OF FIXED INPUTS AS "0#"',/,
     2          1H ,'MAX OF FORMER IS 05 , OF LATTER 02')
      READ(5,2) NV,NF
  2   FORMAT(2I2)
      RETURN
      END
```

```
      SUBROUTINE SMSTR(LPTION,I,J,NV,NF)
      WRITE(6,5)I,J
    5 FORMAT(1H ,/,1H ,'     IF YOU WANT TO CONDUCT SIMULATION NUMBER',
     1         I3,/,1H ,'     FOR COST STRUCTURE NUMBER',I3,/,1H ,
     2                  '              TYPE 1',/,1H ,
     3                  '     IF YOU ARE FINISHED',/,1H ,
     4                  '              TYPE 0',/,1H ,
     5   '     IF YOU WANT TO FULLY RESPECIFY THE COST STRUCTURE,',/,1H ,
     6                  '              TYPE 2',/,1H ,
     7      '     IF YOU TO ALTER THE COST STRUCTURE OR WANT',/,
     8  1H ,'     ANOTHER SET OF PRICES OR QUANTITIES',/,
     9                  '              TYPE 3')
      READ(5,6)LPTION
    6 FORMAT(I1)
      IF(LPTION.EQ.3)CALL NWVAR(NV,NF)
      RETURN
      END

      SUBROUTINE NWVAR(NV,NF)
      COMMON/QUANT/Q
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      WRITE(6,31)
   31 FORMAT(1HO,/,/,1H ,'IF YOU WANT A NEW QUANTITY OF OUTPUT',
     1         /,1H ,' TYPE 1 ;OTHERWISE TYPE ZERO')
      READ(5,32)INDEX
   32 FORMAT(I1)
      IF(INDEX.EQ.0)GO TO 50
      WRITE(6,33)I
   33 FORMAT(1HO,/,1H ,'TYPE NEW QUANTITY OF OUTPUT',I2)
      READ(5,34)Q
   34 FORMAT(F12.3)
   50 CONTINUE
      WRITE(6,20)
   20 FORMAT(1HO,'IF YOU WANT TO CHANGE SOME VARIABLE PRICE, TYPE 1;',
     1            /,1H ,'OTHERWISE, TYPE 0')
      READ(5,2)INDEX
      IF(INDEX.NE.1)GO TO 101
      DO 100 I=1,NV
      WRITE(6,1)I
    1 FORMAT(1HO,/,/,1H ,'IF YOU WANT A NEW PRICE FOR VARIABLE INPUT',
     1             I2,' TYPE 1 ;OTHERWISE TYPE ZERO')
      READ(5,2)INDEX
    2 FORMAT(I1)
      IF(INDEX.EQ.0)GO TO 100
      WRITE(6,3)I
    3 FORMAT(1HO,/,1H ,'TYPE NEW PRICE FOR VARIABLE INPUT',I2)
      READ(5,4)PV(I)
    4 FORMAT(F12.3)
  100 CONTINUE
  101 CONTINUE
      IF(NF.LT.1)GO TO 301
      WRITE(6,21)
   21 FORMAT(1HO,'IF YOU WANT TO CHANGE SOME FIXED QUANTITY, TYPE 1;',
     1            /,1H ,'OTHERWISE, TYPE 0')
```

```
      READ(5,2)INDEX
      IF(INDEX.NE.1)GO TO 201
      DO 200 I=1,NF
      WRITE(6,5)I
 5    FORMAT(1HO,/,/,1H ,'IF YOU WANT A NEW QUANTITY FOR FIXED INPUT',
     1             I2,' TYPE 1 ;OTHERWISE TYPE ZERO')
      READ(5,6)INDEX
 6    FORMAT(I1)
      IF(INDEX.EQ.O)GO TO 200
      WRITE(6,7)I
 7    FORMAT(1HO,/,1H ,'TYPE NEW QUANTITY FOR FIXED INPUT',I2)
      READ(5,8)XF(I)
 8    FORMAT(F12.3)
 200  CONTINUE
 201  CONTINUE
      WRITE(6,22)
 22   FORMAT(1HO,'IF YOU WANT TO CHANGE SOME FIXED INPUT PRICE, TYPE 1:'
     1            /,1H ,'OTHERWISE, TYPE O')
      READ(5,2)INDEX
      IF(INDEX.NE.1)GO TO 301
      DO 300 I=1,NF
      WRITE(6,9)I
 9    FORMAT(1HO,/,/,1H ,'IF YOU WANT A NEW PRICE FOR FIXED INPUT',
     1             I2,' TYPE 1 ;OTHERWISE TYPE ZERO')
      READ(5,12)INDEX
12    FORMAT(I1)
      IF(INDEX.EQ.O)GO TO 300
      WRITE(6,13)I
13    FORMAT(1HO,/,1H ,'TYPE NEW PRICE FOR FIXED INPUT',I2)
      READ(5,14)PF(I)
14    FORMAT(F12.3)
 300  CONTINUE
 301  CONTINUE
      WRITE(4,15)
 15   FORMAT(/,/,/,1H ,'**********************************************',
     1        /,/,1H ,'              NEW ECONOMIC VARIABLES',/,1H ,
     2               '              AND/OR COST STRUCTURE.',/,/,
     3            1H ,'      FOLLOWING HOLD UNTIL FURTHER NOTICE',
     4         /,/,1H ,'**********************************************')
      CALL BSCVAL(NV,NF)
      CALL WRBSVL(NV,NF)
      WRITE(6,30)
 30   FORMAT(1H),/,1H ,'IF YOU WANT SOME CHANGE IN TECHNOLOGY, TYPE 1:',
     1              /,1H ,'OTHERWISE TYPE O')
      READ(5,32)INDEX
      IF(INDEX.EQ.1)CALL TECSET(NV,NF)
      RETURN
      END
```

```
      SUBROUTINE INIT
      COMMON/BEN/BNFTS
      COMMON/QUANT/Q
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/ELASS/ESOREL(5,5),ELASVV(5,5),ELASVF(5,2)
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1                ,SMSHEL(2)
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/SUBPQS/SUBPV(5),SUBXF(2),SW(2),SY(5)
      Q=0.0
      BNFTS=0.0
      BCOST=0.0
      BFXCST=0.0
      DO 100 I=1,5
      BY(I)=0.0
      SY(I)=0.0
      SUBPV(I)=0.0
      PV(I)=0.0
      SHR(I)=0.0
      TVQ(I)=0.0
      A(I)=0.0
      DO 10 J=1,5
      ESOREL(I,J)=0.0
      ELASVV(I,J)=0.0
      AVV(I,J)=0.0
   10 CONTINUE
      DO 20 J=1,2
      GVF(I,J)=0.0
      ELASVF(I,J)=0.0
   20 CONTINUE
  100 CONTINUE
      DO 200 I=1,3
      BFFO(I)=0.0
  200 CONTINUE
      DO 300 I=1,2
      XF(I)=0.0
      PF(I)=0.0
      FQO(I)=0.0
      THFQ(I)=0.0
      BW(I)=0.0
      SW(I)=0.0
      SUBXF(I)=0.0
      H(I)=0.0
      HO(I)=0.0
      DO 45 J=1,2
      BFF(I,J)=0.0
   45 CONTINUE
  300 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INPUT(NV,NF)
      COMMON/QUANT/Q
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/ELASS/ESOREL(5,5),ELASVV(5,5),ELASVF(5,2)
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1                  ,SMSHEL(2)
      WRITE(6,2)
    2 FORMAT(/,/,1H ,'INPUT QUANTITY. USE DECIMAL POINTS IN ALL INPUTS')
      READ(5,3)Q
    3 FORMAT(F12.2)
      WRITE(4,2)
      WRITE(4,33)Q
   33 FORMAT(1H ,F12.2)
      DO 100 I=1,NV
      WRITE(6,31)I
   31 FORMAT(1HO,'INPUT PRICE OF VARIABLE INPUT',3X,I2)
      READ(5,4)PV(I)
      WRITE(6,32)I
   32 FORMAT(1HO,'INPUT SHARE OF VARIABLE INPUT',3X,I2)
      READ(5,4)SHR(I)
    4 FORMAT(F12.2)
      WRITE(4,31)I
      WRITE(4,44)PV(I)
      WRITE(4,32)I
      WRITE(4,44)SHR(I)
   44 FORMAT(1H ,F12.2)
  100 CONTINUE
      WRITE(6,16)
   16 FORMAT(1HO,'INPUT BASE COST LEVEL')
      READ(5,4)BASE
      WRITE(4,16)
      WRITE(4,44)BASE
      IF(NF.EQ.O)GO TO 201
      DO 200 I=1,NF
      WRITE(6,5)I
    5 FORMAT(1HO,'INPUT QUANTITY OF FIXED INPUT',3X,I2)
      READ(5,4)XF(I)
C     WRITE(6,6)I
C   6 FORMAT(1HO,'INPUT BFFO, OWN SQUARE COEFF, FOR FIXED INPUT',3X,I2)
C     READ(5,4)BFFO(I)
C     IF(I.LT.2)GO TO 69
C     WRITE(6,66)
C  66 FORMAT(1HO,'INPUT CROSS BFFO FOR FIXED INPUTS',3X,I2)
C     READ(5,4)BFFO(3)
   69 CONTINUE
      WRITE(6,666)I
  666 FORMAT(1HO,'INPUT SOCIAL PRICE OF FIXED INPUT',3X,I2)
      READ(5,4)PF(I)
      WRITE(4,5)I
      WRITE(4,44)XF(I)
      WRITE(4,666)I
      WRITE(4,44)PF(I)
C     WRITE(4,6)I
C     WRITE(4,44)BFFO(I)
```

```
C      IF(I.LT.2)GO TO 70
C      WRITE(4,66)
C      WRITE(4,44)BFFO(3)
   70  CONTINUE
  200  CONTINUE
  201  CONTINUE
       NVM1=NV-1
       DO 300 I=1,NVM1
       II=I
       IP1=I+1
       IF(IP1.GT.NV)GO TO 400
       DO 300 J=IP1,NV
       JJ=J
       WRITE(6,9)I,J
    9  FORMAT(1HO,'INPUT ELAS. OF SUBST. FOR VARIABLE INPUTS',
      1                                        1X,I2,1X,'AND',1X,I2,1X)
       READ(5,4)ELASVV(I,J)
       ELASVV(J,I)=ELASVV(I,J)
       WRITE(4,9)I,J
       WRITE(4,44)ELASVV(I,J)
  300  CONTINUE
  400  CONTINUE
       IF(NF.EQ.O)GO TO 501
       DO 500 I=1,NV
       DO 500 J=1,NF
       WRITE(6,10)I,J
   10  FORMAT(1HO,'INPUT ELAS. OF VARIABLE INPUT',1X,I2,1X,
      1             'WITH RESPECT TO FIXED INPUT',1X,I2)
       READ(5,4)ELASVF(I,J)
       WRITE(4,10)I,J
       WRITE(4,44)ELASVF(I,J)
  500  CONTINUE
  501  CONTINUE
       RETURN
       END


       SUBROUTINE SETPAR(NV,NF)
       COMMON/QUANT/Q
       COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
       COMMON/ELASS/ESOREL(5,5),ELASVV(5,5),ELASVF(5,2)
       COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
      1             ,SMSHEL(2)
C*****************************************************************
C                SET AVV FOR I NE J
C*****************************************************************
       NVM1=NV-1
       DO 100 I=1,NVM1
       IP1=I+1
       DO 100 J=IP1,NV
       AVV(I,J)=ELASVV(I,J)*(SHR(I)*SHR(J))-SHR(I)*SHR(J)
       AVV(J,I)=AVV(I,J)
  100  CONTINUE
       IF(NF.EQ.O)GO TO 281
```

```
C*****************************************************************
C                    SET GVF USING INITIAL SHADOW SHARES
C*****************************************************************
      NVM1=NV-1
      DO 250 J=1,NF
      SUMGVF=0.
      SMSHEL(J)=0.
      DO 150 K=1,NV
      SMSHEL(J)=SMSHEL(J) + SHR(K)*ELASVF(K,J)
  150 CONTINUE
      DO 200 I=1,NVM1
      GVF(I,J)=SHR(I)*ELASVF(I,J)-SMSHEL(J)*SHR(I)
      SUMGVF=SUMGVF+GVF(I,J)
  200 CONTINUE
      GVF(NV,J)=-SUMGVF
      BFF(J,J)=-(SMSHEL(J)**2)
  250 CONTINUE
C******************************************************************
C                              SET TVQ
C******************************************************************
      DO 280 I=1,NVM1
      SMGVFF=0.0
      DO 275 J=1,NF
      SMGVFF=SMGVFF+GVF(I,J)
  275 CONTINUE
      TVQ(I)=-SMGVFF
  280 CONTINUE
  281 CONTINUE
      SUMTVQ=0.0
      DO 290 I=1,NVM1
  290 SUMTVQ=SUMTVQ+TVQ(I)
      TVQ(NV)=-SUMTVQ
C****************************************************************
C                         SET AVV FOR I=J
C****************************************************************
      DO 400 I=1,NV
      SUMAVV=0
      DO 300 J=1,NV
      IF(J.NE.I)SUMAVV=SUMAVV+AVV(I,J)
  300 CONTINUE
      AVV(I,I)=-SUMAVV
  400 CONTINUE
C*****************************************************************
C                          SET A(V)
C*****************************************************************
      DO 500 I=1,NV
      SUMVVP=0
      SUMVFX=0
      DO 450 J=1,NV
  450 SUMVVP=SUMVVP+AVV(I,J)*LOG(PV(J))
      IF(NF.EQ.0)GO TO 476
      DO 475 K=1,NF
      SUMVFX=SUMVFX+GVF(I,K)*LOG(XF(K))
  475 CONTINUE
```

```
  476 CONTINUE
      A(I)=( SHR(I)-SUMVVP -SUMVFX ) - LOG(Q)*TVQ(I)
  500 CONTINUE
      IF(NF.EQ.0)GO TO 4501
C*******************************************************************
C                                SET BFF
C*******************************************************************
      DO 3000 I=1,NF
      IF(I.EQ.1)GO TO 1000
      BFF(1,2)=0
      BFF(2,1)=0
C     BFF(2,2)=BFFO(2)
C     GO TO 2000
 1000 CONTINUE
C     BFF(1,1)=BFFO(1)
C2000 CONTINUE
 3000 CONTINUE
C********************************************************************
C                                   SET THFQ
C********************************************************************
      DO 4000 I=1,NF
      SUMBFF=0.0
      DO 3500 J=1,NF
      SUMBFF=SUMBFF+BFF(I,J)
 3500 CONTINUE
      THFQ(I)=-SUMBFF
 4000 CONTINUE
C********************************************************************
C                                   SET H(F)
C********************************************************************
      DO 4500 I=1,NF
      SMGVF=0.
      SMBFF=0.
      DO 4100 J=I,NV
      SMGVF=SMGVF+GVF(J,I)*LOG(PV(J))
 4100 CONTINUE
      DO 4200 J=1,NF
      SMBFF=SMBFF+BFF(I,J)*LOG(XF(J))
 4200 CONTINUE
      H(I)=SMSHEL(I)-SMBFF-SMGVF-THFQ(I)*LOG(Q)
 4500 CONTINUE
 4501 CONTINUE
C*********************************************************************
C                      SET ZQ ( COEFFICIENT OF LOG(Q) )
C*********************************************************************
      SUMH=0.
      IF(NF.LT.1)GO TO 4506
      DO 4505 I=1,NF
      SUMH=SUMH+H(I)
 4505 CONTINUE
 4506 CONTINUE
      ZQ=1-SUMH
```

```
C*********************************************************************
C                       SET BASE (CONSTANT TERM)
C*********************************************************************
      SV=0.
      SF=0.
      SVV=0.
      SVF=0.
      SFF=0.
      SVQ=0.
      SFQ=0.
      DO 5000 I=1,NV
      SV=SV+A(I)*LOG(PV(I))
      SVQ=SVQ+TVQ(I)*LOG(Q)*LOG(PV(I))
      DO 4600 J=1,NV
      SVV=SVV+.5*AVV(I,J)*LOG(PV(I))*LOG(PV(J))
 4600 CONTINUE
      IF(NF.EQ.0)GO TO 4701
      DO 4700 K=1,NF
      SVF=SVF+GVF(I,K)*LOG(PV(I))*LOG(XF(K))
      IF(I.GT.1)GO TO 4700
      SFQ=SFQ+THFQ(K)*LOG(XF(K))*LOG(Q)
      SF=SF+H(K)*LOG(XF(K))
      DO 4650 L=1,NF
      SFF=SFF+.5*BFF(K,L)*LOG(XF(K))*LOG(XF(L))
 4650 CONTINUE
 4700 CONTINUE
 4701 CONTINUE
 5000 CONTINUE
      BASE=LOG(BASE)-SV-SF-SVV-SVF-SFF-SVQ-SFQ-ZQ*LOG(Q)
      CALL TECH
      RETURN
      END

      SUBROUTINE BSCVAL(NV,NF)
      COMMON/QUANT/Q
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1        ,SMSHEL(2)
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
C**********************************************************************
C                        CHECK FOR A GIFFEN GOOD
C**********************************************************************
      ICALL=-1
      IG=0
      CALL GIFCHK(NV,NF,ICALL,IG,SUBPVL,SUBPVH)
      IF(IG.EQ.0)GO TO 1
      IF(IG.EQ.1)RETURN
      WRITE(4,2)
  2   FORMAT(1H ,'BASIC VALUES INCLUDE MULTIPLE GIFFEN EFFECTS')
C*********************************************************************
C                                INITIALIZE
C*********************************************************************
  1   BFXCST=0.0
      SUMLV1=0.0
```

```
      SUMLF1=0.0
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      SUM4=0.0
      SUM5=0.0
C***********************************************************************
C                    ACCUMULATE PARTS OF COST FUNCTION
C***********************************************************************
      DO 200 I=1,NV
      SUMLV1=SUMLV1+A(I)*LOG(PV(I))
      DO 100 J=1,NV
 100  SUM1=SUM1+.5*AVV(I,J)*LOG(PV(I))*LOG(PV(J))
      IF(NF.EQ.0)GO TO 151
      DO 150 K=1,NF
      SUM2=SUM2+GVF(I,K)*LOG(PV(I))*LOG(XF(K))
 150  CONTINUE
 151  CONTINUE
      SUM3=SUM3+TVQ(I)*LOG(PV(I))*LOG(Q)
 200  CONTINUE
      IF(NF.EQ.0)GO TO 401
      DO 400 I=1,NF
      SUMLF1=SUMLF1+H(I)*LOG(XF(I))
      DO 300 J=1,NF
 300  SUM4=SUM4+.5*BFF(I,J)*LOG(XF(I))*LOG(XF(J))
      SUM5=SUM5+THFQ(I)*LOG(XF(I))*LOG(Q)
 400  CONTINUE
 401  CONTINUE
C***********************************************************************
C                      COMPUTE LOG COST & COST
C***********************************************************************
      BLGCST=SUM1+SUM2+SUM3+SUM4+SUM5+SUMLV1+SUMLF1+BASE+ZQ*LOG(Q)
      BCOST=EXP(BLGCST)
C***********************************************************************
C                    COMPUTE VARIABLE INPUT DEMANDS
C***********************************************************************
      DO 700 I=1,NV
      SSUM1=0.0
      SSUM2=0.0
      DO 500 J=1,NV
 500  SSUM1=SSUM1+AVV(I,J)*LOG(PV(J))
      IF(NF.EQ.0)GO TO 601
      DO 600 K=1,NF
      SSUM2=SSUM2+GVF(I,K)*LOG(XF(K))
 600  CONTINUE
 601  CONTINUE
      BY(I)=(BCOST/PV(I))*(A(I)+SSUM1+SSUM2+TVQ(I)*LOG(Q))
 700  CONTINUE
      IF(NF.EQ.0)GO TO 1101
C***********************************************************************
C                   COMPUTE FIXED INPUT SHADOW PRICES
C***********************************************************************
      DO 1000 I=1,NF
      SSSUM1=0.0
```

```
      SSSUM2=0.0
      DO 800 J=1,NV
  800 SSSUM1=SSSUM1+GVF(J,I)*LOG(PV(J))
      DO 900 K=1,NF
  900 SSSUM2=SSSUM2+BFF(I,K)*LOG(XF(K))
      BW(I)=-1.*(BCOST/XF(I))*(H(I)+SSSUM1+SSSUM2+THFQ(I)*LOG(Q))
 1000 CONTINUE
C**********************************************************************
C                    COMPUTE FIXED COST AT SOCIAL PRICES
C**********************************************************************
      DO 1100 I=1,NF
      BFXCST=PF(I)*XF(I)+BFXCST
 1100 CONTINUE
 1101 CONTINUE
      RETURN
      END


      SUBROUTINE WRBSVL(NV,NF)
      COMMON/QUANT/Q
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      WRITE(4,1)Q,BCOST
    1 FORMAT(/,1H ,'FIRM OUTPUT=',F12.3,/1H ,'INITIAL COST=',F11.3)
      DO 100 I=1,NV
      WRITE(4,2)I,BY(I)
    2 FORMAT(1H ,/,/,1H ,'INITIAL DEMAND FOR VARIABLE INPUT',
     1            I2,2X,'=',F12.3)
      WRITE(4,4)I,PV(I)
    4 FORMAT(1H ,'INITIAL PRICE FOR VARIABLE INPUT',I2,2X,'=',F12.3)
  100 CONTINUE
      IF(NF.EQ.0)GO TO 201
      DO 200 J=1,NF
      WRITE(4,3)J,BW(J)
    3 FORMAT(1H ,/1H ,'INITIAL SHADOW VALUE OF FIXED INPUT',I2,2X,'=',
     1               F12.3)
      WRITE(4,5)J,XF(J)
    5 FORMAT(1H ,'INITIAL QUANTITY FOR FIXED INPUT',I2,2X,'=',F12.3)
      WRITE(4,6)J,PF(J)
    6 FORMAT(1H ,'INITIAL SOCIAL PRICE FOR FIXED INPUT',I2,2X,'=',F12.3)
  200 CONTINUE
  201 CONTINUE
      RETURN
      END


      SUBROUTINE TOL
      COMMON/TOL1/TOLER
      TOLER=.0001
C     WRITE(6,1)
 1    FORMAT(1HO,/,/,1H ,'DO YOU WANT THE DEFAULT TOLERANCE THAT',/,
     1              1H ,'YIELDS BENEFITS WITHIN 1/2 PERCENT OF',/,
     2              1H ,'BENEFITS SPECIFIED FOR SIMULATION?',/,
     3              1H ,'IF YES, TYPE 1; OTHERWISE TYPE 0.')
```

```
C     READ(5,2)J
 2    FORMAT(I1)
C     IF(J.EQ.1)GO TO 100
C     WRITE(6,3)
 3    FORMAT(/,1H ,'ENTER THE DESIRED TOLERANCE AS A DECIMAL FRACTION',
     1        /,1H ,'EG., .005 IS THE DEFAULT LEVEL YOU HAVE REJECTED')
C     READ(5,4)TOLER
C4    FORMAT(F6.3)
C     TOLERP=100*TOLER
C100  WRITE(4,5)TOLERP
 5    FORMAT(1H ,/,/,1H ,'ESTIMATES OF BENEFITS WILL BE WITHIN ',F4.2,
     1                2X,'PERCENT OF SPECIFIED BENEFIT LEVEL')
      RETURN
      END


      SUBROUTINE BENSET(NUM,NV,NF,JNEGSH)
      COMMON/BEN/BNFTS
      IF(NUM.GT.1)WRITE(6,10)
   10 FORMAT(1HO,/,1H ,'IF YOU WANT SAME BENEFITS AS LAST',/,1H ,
     1                 'SIMULATION FOR THIS COST STUCTURE',/,1H ,
     2                 'TYPE 1')
      WRITE(6,11)
   11 FORMAT(1H ,'IF YOU WANT TO SET A NEW BENEFIT LEVEL',/,1H ,
     1           'TYPE 2')
      WRITE(6,12)
   12 FORMAT(1H ,'IF YOU WANT BENEFIT LEVEL SET BY THE SCHEME',/,1H ,
     1           'TYPE 3')
      READ(5,13)LPTBEN
   13 FORMAT(I1)
      IF(LPTBEN.NE.2)GO TO 3
      WRITE(6,14)
   14 FORMAT(1H ,/,1H ,'INPUT LEVEL OF BENEFITS')
      READ(5,15)BNFTS
   15 FORMAT(F12.2)
    3 IF(LPTBEN.NE.3)WRITE(4,16)BNFTS,NUM
   16 FORMAT(1H ,/,/,/,1H ,'         BENEFITS=',F12.2,2X,'IN SCHEME',I3)
C     CALL CHECK2
      JNEGSH=0
      IF(LPTBEN.NE.3)CALL BINSR(NV,NF,JNEGSH)
      IF(LPTBEN.EQ.3)CALL SUBBEN(NUM,NV,NF)
      RETURN
      END

      SUBROUTINE BINSR(NV,NF,JNEGSH)
      COMMON/SUBIND/JSUBV,JSUBF
      COMMON/BEN/BNFTS
      COMMON/QUANT/Q
      COMMON/TOL1/TOLER
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1             ,SMSHEL(2)
```

```
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/SUBPQS/SUBPV(5),SUBXF(2),SW(2),SY(5)
      JSUBF=0
      WRITE(6,1)
    1 FORMAT(1H0,'TYPE INTEGER OF VARIABLE INPUT TO SUBSIDIZE.',/,1H ,
     1           'IF SUBSIDIZING FIXED INPUT, TYPE 0')
      READ(5,2)JSUBV
    2 FORMAT(I1)
      IF(JSUBV.GT.0)WRITE(4,3)JSUBV
    3 FORMAT(1H ,/1H ,'SCHEME SUBSIDIZES VARIABLE INPUT',I2)
      IF(JSUBV.GT.0)GO TO 10
      WRITE(6,4)
    4 FORMAT(1H0,'TYPE INTEGER OF FIXED INPUT TO SUBSIDIZE')
      READ(5,2)JSUBF
      WRITE(4,5)JSUBF
    5 FORMAT(1H ,/1H ,'SCHEME SUBSIDIZES FIXED INPUT',I2)
      IF(BW(JSUBF).GT.0)GO TO 10
      WRITE(6,7)JSUBF
      WRITE(4,7)JSUBF
    7 FORMAT(1H0,/,1H ,'FIXED INPUT',I2,2X,'HAS A NEGATIVE SHADOW',
     1                ' PRICE; INCREMENTS YIELD NO BENEFITS')
      JNEGSH=1
      RETURN
   10 CONTINUE
C***********************************************************************
C               SET INITIAL BOUNDS FOR SUBSIDIZED PRICE
C                       OF VARIABLE INPUT
C***********************************************************************
      DO 20 I=1,NV
   20 SUBPV(I)=PV(I)
      IF(NF.EQ.0)GO TO 31
      DO 30 J=1,NF
      SUBXF(J)=XF(J)
   30 CONTINUE
   31 CONTINUE
      IQUERY=0
      IF(JSUBF.GT.0)GO TO 90
      SUBPVL=PV(JSUBV)-BNFTS/BY(JSUBV)
      SUBPVH=PV(JSUBV)
      IF(SUBPVL.GT.0)GO TO 98
C***********************************************************************
C               CHECK IF BENEFITS POTENTIALLY TOO BIG FOR
C                     THIS VARIABLE INPUT
C***********************************************************************
      SUBPVL=.0001
      SUBPV(JSUBV)=.1*SUBPVL+.9*SUBPVH
      ICALL=JSUBV
      CALL GIFCHK(NV,NF,ICALL,IG,SUBPVL,SUBPVH)
      IF(IG.EQ.1)RETURN
      IQUERY=1
      GO TO 98
   90 CONTINUE
```

```
C*****************************************************************
C           SET INITIAL CONDITIONAL BOUNDS FOR SUBSIDIZED
C                 QUANTITY OF FIXED INPUT
C*****************************************************************
      XFMULT=10.
      SUBXFL=XF(JSUBF)+BNFTS/BW(JSUBF)
      SUBXFH=XF(JSUBF)+(BNFTS+XFMULT*BCOST)/BW(JSUBF)
C*****************************************************************
C           CHECK INITIAL UPPER BOUND ON SUBSIDIZED
C                 FIXED INPUT QUANTITY
C               AND REVISE IF NECESSARY
C*****************************************************************
      XFMLTO=XFMULT
      CALL HSBXFC(NV,NF,SUBXFH,JSUBF,XFMULT,JNEGSH)
      IF(JNEGSH.EQ.1)RETURN
 95   RATIO=XFMULT/XFMLTO
      IF(RATIO.LT.5)GO TO 98
      SUBXFH=XF(JSUBF)+(BNFTS+XFMULT*BCOST)/BW(JSUBF)
      IF(JNEGSH.EQ.1)RETURN
      CALL HSBXFC(NV,NF,SUBXFH,JSUBF,XFMULT,JNEGSH)
      GO TO 95
C*****************************************************************
C               INITIALIZE VARIABLES FOR CHECKING
C               INCREASINGNESS OF COST FUNCTION
C               IN PRICES AND 1/(FIXED INPUTS)
C*****************************************************************
 98   ITER=0
      SCOSTL=0.
      PUP=0.
 99   CONTINUE
      ITER=ITER+1
      IF(IQUERY.EQ.1.AND.ITER.EQ.1)GO TO 100
C*****************************************************************
C               GUESS SUBSIDIZED PRICE OR QUANTITY
C                 AND CHECK FOR GIFFEN EFFECTS
C*****************************************************************
      IF(JSUBV.EQ.0)GO TO 1234
      SUBPV(JSUBV)= .5*(SUBPVH+SUBPVL)
      ICALL=JSUBV
      CALL GIFCHK(NV,NF,ICALL,IG,SUBPVL,SUBPVH)
      IF(IG.EQ.1)RETURN
 1234 IF(JSUBV.EQ.0)SUBXF(JSUBF)=.5*(SUBXFH+SUBXFL)
C*****************************************************************
C             INITIALIZE PARTS OF COST FUNCTION
C*****************************************************************
 100  SUMLV1=0.0
      SUMLF1=0.0
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      SUM4=0.0
      SUM5=0.0
C*****************************************************************
C               COMPUTE PARTS OF COST FUNCTION
```

```
C*********************************************************************
      DO 200 I=1,NV
      SUMLV1=SUMLV1+A(I)*LOG(SUBPV(I))
      DO 110 J=1,NV
      SUM1=SUM1+.5*AVV(I,J)*LOG(SUBPV(I))*LOG(SUBPV(J))
 110  CONTINUE
      IF(NF.EQ.0)GO TO 151
      DO 150 K=1,NF
      SUM2=SUM2+GVF(I,K)*LOG(SUBPV(I))*LOG(SUBXF(K))
 150  CONTINUE
 151  CONTINUE
      SUM3=SUM3+TVQ(I)*LOG(SUBPV(I))*LOG(Q)
 200  CONTINUE
      IF(NF.EQ.0)GO TO 401
      DO 400 I=1,NF
      SUMLF1=SUMLF1+H(I)*LOG(SUBXF(I))
      DO 300 J=1,NF
 300  SUM4=SUM4+.5*BFF(I,J)*LOG(SUBXF(I))*LOG(SUBXF(J))
      SUM5=SUM5+THFQ(I)*LOG(SUBXF(I))*LOG(Q)
 400  CONTINUE
 401  CONTINUE
C*********************************************************************
C                      COMPUTE LOG COST & COST
C                    AND ASSOCIATED BENEFIT LEVEL
C*********************************************************************
      SLGCST=SUM1+SUM2+SUM3+SUM4+SUM5+SUMLV1+SUMLF1+BASE+ZQ*LOG(Q)
      SCOST=EXP(SLGCST)
      BENGS=BCOST-SCOST
C*********************************************************************
C                      CHECK INCREASINGNESS OF
C                          COST FUNCTION
C*********************************************************************

      IF(ITER.EQ.1.AND.BENGS.LT.0)WRITE(6,6)ITER
      IF(ITER.EQ.1.AND.BENGS.LT.0)WRITE(4,6)ITER
    6 FORMAT(1H ,/1H ,'COSTS RISE AS PRICES FALL OR INPUT CANNOT YIELD',
     1' BENEFITS',/,1H ,'JOB SKIPS SCHEME; ITER=',I8,
     2  /,1H ,'TYPE 1 TO ACKNOWLEDGE PROBLEM')
      IF(ITER.EQ.1.AND.BENGS.LT.0)READ(5,83)KKK
   83 FORMAT(I1)
      IF(ITER.EQ.1.AND.BENGS.LT.0)JNEGSH=1
      IF(ITER.EQ.1.AND.BENGS.LT.0)RETURN
      DISCR=(ABS(BENGS-BNFTS))/BNFTS
      CHK=(SCOST-SCOSTL)*PUP
      IF(ITER.GT.1.AND.CHK.LT.0)WRITE(6,6)ITER
      IF(ITER.GT.1.AND.CHK.LT.0)WRITE(4,6)ITER
      IF(ITER.GT.1.AND.CHK.LT.0)READ(5,83)KKK
      IF(ITER.GT.1.AND.CHK.LT.0)JNEGSH=1
      IF(ITER.GT.1.AND.CHK.LT.0)RETURN
      SCOSTL=SCOST
C*********************************************************************
C                      CHECK BENEFIT GUESS FOR
C                     CLOSENESS TO NEEDED LEVEL
C*********************************************************************
```

```
      IF(DISCR.LT.TOLER)GO TO 499
      IF(JSUBV.EQ.0)GO TO 425
C***********************************************************************
C                     CHECK IF ZERO PRICE NOT
C                  ENOUGH TO YIELD NEEEDED LEVEL
C***********************************************************************
      IIQ=0
      IF(IQUERY.EQ.1.AND.SUBPV(JSUBV).LT. .001)IIQ=1
      IF(IIQ.EQ.1)WRITE(4,66)
      IF(IIQ.EQ.1)WRITE(6,66)
      IF(IIQ.EQ.1)READ(5,83)KKK
      IF(IIQ.EQ.1)JNEGSH=1
      IF(IIQ.EQ.1)RETURN
   66 FORMAT(1H ,/1H ,'ZERO PRICE NOT ENOUGH TC YIELD BENEFIT LEVEL',
     1     /,1H ,'SKIP TO NEXT SCHEME; TYPE 1 TO ACKNOWLEDGE PROBLEM')
C***********************************************************************
C                        RESET BOUNDS ON
C                        SUBSIDIZED PRICE
C***********************************************************************
      IF(BENGS.GT.BNFTS)SUBPVL=SUBPV(JSUBV)
      IF(BENGS.GT.BNFTS)PUP=1.
      IF(BENGS.LE.BNFTS)SUBPVH=SUBPV(JSUBV)
      IF(BENGS.LE.BNFTS)PUP=-1.
      GO TO 99
  425 CONTINUE
C***********************************************************************
C                        RESET BOUNDS ON
C                      SUBSIDIZED QUANTITY
C***********************************************************************
      IF(BENGS.LE.BNFTS)SUBXFL=SUBXF(JSUBF)
      IF(BENGS.LE.BNFTS)PUP=-1.
      IF(BENGS.GT.BNFTS)SUBXFH=SUBXF(JSUBF)
      IF(BENGS.GT.BNFTS)PUP=1.0
      GO TO 99
  499 CONTINUE
      CALL SUBOUT(NV,NF)
      RETURN
      END


      SUBROUTINE HSBXFC(NV,NF,SUBXFH,JSUBF,XFMULT,JNEGSH)
      COMMON/BEN/BNFTS
      COMMON/QUANT/Q
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1             ,SMSHEL(2)
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/SUBPQS/SUBPV(5),SUBXF(2),SW(2),SY(5)
      COMMON/SSXFS/SSUBXF(2)
      DO 10 I=1,NF
   10 SSUBXF(I)=SUBXF(I)
      SSUBXF(JSUBF)=SUBXFH
      SUMLV1=0.0
      SUMLF1=0.0
```

```
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      SUM4=0.0
      SUM5=0.0
      SV=0.
      SF=0.
      DO 200 I=1,NV
      SUMLV1=SUMLV1+A(I)*LOG(SUBPV(I))
      SV=SV+GVF(I,JSUBF)*LOG(SUBPV(I))
      DO 100 J=1,NV
100   SUM1=SUM1+.5*AVV(I,J)*LOG(SUBPV(I))*LOG(SUBPV(J))
      DO 150 K=1,NF
150   SUM2=SUM2+GVF(I,K)*LOG(SUBPV(I))*LOG(SSUBXF(K))
      SUM3=SUM3+TVQ(I)*LOG(SUBPV(I))*LOG(Q)
200   CONTINUE
      DO 400 I=1,NF
      SUMLF1=SUMLF1+H(I)*LOG(SSUBXF(I))
      SF=SF+BFF(I,JSUBF)*LOG(SSUBXF(I))
      DO 300 J=1,NF
300   SUM4=SUM4+.5*BFF(I,J)*LOG(SSUBXF(I))*LOG(SSUBXF(J))
      SUM5=SUM5+THFQ(I)*LOG(SSUBXF(I))*LOG(Q)
400   CONTINUE
      SLGCST=SUM1+SUM2+SUM3+SUM4+SUM5+SUMLV1+SUMLF1+BASE+ZQ*LOG(Q)
      SCOST=EXP(SLGCST)
      BENGS=BCOST-SCOST
      IF(BENGS.GE.BNFTS)GO TO 500
      XFMULT=10*XFMULT
      SW(JSUBF)=-1.0*(SCOST/SSUBXF(JSUBF))*(H(JSUBF)+SV+SF
     1                       +THFQ(JSUBF)*LOG(Q))
      IF(SW(JSUBF).GT.0)GO TO 500
      WRITE(4,1)JSUBF
 1    FORMAT(1H ,/,1H ,'FIXED INPUT',I2,' CANNOT YIELD ENOUGH BENEFITS')
      JNEGSH=1
500   CONTINUE
      RETURN
      END


      SUBROUTINE SUBOUT(NV,NF)
      COMMON/BEN/BNFTS
      COMMON/QUANT/Q
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1            ,SMSHEL(2)
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/SUBPQS/SUBPV(5),SUBXF(2),SW(2),SY(5)
C*********************************************************************
C                       COMPUTE SUBSIDIZED DEMANDS
C*********************************************************************
      DO 900 I=1,NV
      SSUM1=0.0
      SSUM2=0.0
      DO 500 J=1,NV
```

```
 500   SSUM1=SSUM1+AVV(I,J)*LOG(SUBPV(J))
       IF(NF.EQ.0)GO TO 601
       DO 600 K=1,NF
       SSUM2=SSUM2+GVF(I,K)*LOG(SUBXF(K))
 600   CONTINUE
 601   CONTINUE
       SY(I)=(SCOST/SUBPV(I))*(A(I)+SSUM1+SSUM2+TVQ(I)*LOG(Q))
       WRITE(4,602)I,SUBPV(I),SY(I)
  602 FORMAT(1H ,/1H ,'SUBSIDIZED PRICE FOR VARIABLE INPUT',I2,2X,'=',
     1 F12.2,/,1H ,'SUBSIDIZED QUANTITY OF THAT VARIABLE INPUT =',F12.3)
  900 CONTINUE
      IF(NF.EQ.0)GO TO 1001
C**** ******************************************************************
C                  COMPUTE SUBSIDIZED SHADOW PRICES
C**********************************************************************
      DO 1000 I=1,NF
      SSSUM1=0.0
      SSSUM2=0.0
      DO 800 J=1,NV
 800  SSSUM1=SSSUM1+GVF(J,I)*LOG(SUBPV(J))
      DO 950 K=1,NF
 950  SSSUM2=SSSUM2+BFF(I,K)*LOG(SUBXF(K))
      SW(I)=-1.*(SCOST/SUBXF(I))*(H(I)+SSSUM1+SSSUM2+THFQ(I)*LOG(Q))
      WRITE(4,701)I,SW(I),SUBXF(I)
  701 FORMAT(1H ,/1H ,'SUBSIDIZED SHADOW PRICE OF FIXED INPUT',I2,2X,
     1'=',F12.3,/,1H ,'SUBSIDIZED QUANTITY OF THAT FIXED INPUT =',F12.3)
1000  CONTINUE
1001  CONTINUE
C***********************************************************************
C
C                        CHECK FOR UPWARD SLOPING
C                           FACTOR DEMANDS
C
C***********************************************************************
      DO 2000 I=1,NV
      SHTRM=( SUBPV(I)*SY(I)/SCOST)*((SUBPV(I)*SY(I)/SCOST)-1)
      CHQ=AVV(I,I)+SHTRM
      IF(CHQ.GT.0.)WRITE(4,2001)I
 2001 FORMAT(1H ,/,'VARIABLE INPUT',I2,' IS GIFFEN')
 2000 CONTINUE
      RETURN
      END


      SUBROUTINE SUBBEN(NUM,NV,NF)
      COMMON/SUBIND/JSUBV,JSUBF
      COMMON/BEN/BNFTS
      COMMON/QUANT/Q
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1             ,SMSHEL(2)
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/SUBPQS/SUBPV(5),SUBXF(2),SW(2),SY(5)
      COMMON/SSXFS/SSUBXF(2)
```

```
      JSUBV=0
      JSUBF=0
C***********************************************************************
C                    SET SUBSIDIZED PRICES AND
C                           QUANTITIES
C***********************************************************************
      DO 10 I=1,NV
      WRITE(6,1)I
  1   FORMAT(1H0,/,1H ,'IF VARIABLE INPUT',I2,2X,'IS TO BE SUBSIDIZED',
     1                /,1H ,'           TYPE 1; OTHERWISE TYPE 0')
      READ(5,2)INDEX
  2   FORMAT(I1)
      IF(INDEX.EQ.0)SUBPV(I)=PV(I)
      IF(INDEX.EQ.0)GO TO 10
      JSUBV=1
      WRITE(6,3)I
  3   FORMAT(1H0,/,1H ,'INPUT SUBSIDIZED PRICE FOR VARIABLE INPUT',I2)
      READ(5,4)SUBPV(I)
  4   FORMAT(F12.2)
 10   CONTINUE
      IF(NF.EQ.0)GO TO 21
      DO 20 I=1,NF
      WRITE(6,5)I
  5   FORMAT(1H0,/,1H ,'IF FIXED INPUT',I2,2X,'IS TO BE SUBSIDIZED',
     1                /,1H ,'           TYPE 1; OTHERWISE TYPE 0')
      READ(5,6)INDEX
  6   FORMAT(I1)
      IF(INDEX.EQ.0)SUBXF(I)=XF(I)
      IF(INDEX.EQ.0)GO TO 20
      IF(I.EQ.1)JSUBF=1
      IF(I.EQ.2 .AND. JSUBF.EQ.1)JSUBF=3
      IF(I.EQ.2 .AND. JSUBF.EQ.0)JSUBF=2
      WRITE(6,7)I
  7   FORMAT(1H0,/,1H ,'INPUT SUBSIDIZED QUANTITY FOR FIXED INPUT',I2)
      READ(5,8)SUBXF(I)
  8   FORMAT(F12.2)
 20   CONTINUE
 21   CONTINUE
C***********************************************************************
C                       CHECK FOR GIFFEN EFFECTS
C***********************************************************************
      ICALL=0
      CALL GIFCHK(NV,NF,ICALL,IG,SUBPVL,SUBPVH)
      IF(IG.EQ.1)RETURN
C***********************************************************************
C                      INITIALIZE ELEMENTS OF
C                         SUBSIDIZED COSTS
C***********************************************************************
      SUMLV1=0.0
      SUMLF1=0.0
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      SUM4=0.0
```

```
      SUMS=0.0
C*************************************************************************
C                         COMPUTE ELEMENTS OF
C                          SUBSIDIZED COSTS
C*************************************************************************
      DO 200 I=1,NV
      SUMLV1=SUMLV1+A(I)*LOG(SUBPV(I))
      DO 100 J=1,NV
 100  SUM1=SUM1+.5*AVV(I,J)*LOG(SUBPV(I))*LOG(SUBPV(J))
      IF(NF.EQ.O)GO TO 151
      DO 150 K=1,NF
      SUM2=SUM2+GVF(I,K)*LOG(SUBPV(I))*LOG(SUBXF(K))
 150  CONTINUE
 151  CONTINUE
      SUM3=SUM3+TVQ(I)*LOG(SUBPV(I))*LOG(Q)
 200  CONTINUE
      IF(NF.EQ.O)GO TO 401
      DO 400 I=1,NF
      SUMLF1=SUMLF1+H(I)*LOG(SUBXF(I))
      DO 300 J=1,NF
 300  SUM4=SUM4+.5*BFF(I,J)*LOG(SUBXF(I))*LOG(SUBXF(J))
      SUM5=SUM5+THFQ(I)*LOG(SUBXF(I))*LOG(Q)
 400  CONTINUE
 401  CONTINUE
C*************************************************************************
C                  COMPUTE LOG COST, COST, & BENEFITS
C                            UNDER SUBSIDY
C*************************************************************************
      SLGCST=SUM1+SUM2+SUM3+SUM4+SUM5+SUMLV1+SUMLF1+BASE+ZQ*LOG(Q)
      SCOST=EXP(SLGCST)
      BENGS=BCOST-SCOST
      BNFTS=BENGS
      WRITE(4,16)BNFTS,NUM
  16  FORMAT(1HO,/,/,/,1H ,'         BENEFITS=',F12.2,2X,'IN SCHEME',I3)

      WRITE(4,98)
  98  FORMAT(1H ,/,/,/,/,
     1    '                THESE BENEFITS ARE FROM THE',/,1H ,
     2    '                FOLLOWING SUBSIDY SCHEME')
      WRITE(4,97)
  97  FORMAT(1H ,/)
      DO 30 I=1,NV
      WRITE(4,9)I,SUBPV(I)
   9  FORMAT(1H ,/,1H ,'SUBSIDIZED PRICE FOR VARIABLE INPUT',I2,1X,
     1          '=',F12.2)
  30  CONTINUE
      IF(NF.EQ.O)GO TO 41
      DO 40 I=1,NF
      WRITE(4,99)I,SUBXF(I)
  99  FORMAT(1H ,/,1H ,'SUBSIDIZED QUANTITY FOR FIXED INPUT',I2,1X,'=',
     1            F12.2)
  40  CONTINUE
  41  CONTINUE
      CALL SUBOUT(NV,NF)
```

```
      RETURN
      END

      SUBROUTINE PQCHGS(NUM,NV,NF)
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/SUBPQS/SUBPV(5),SUBXF(2),SW(2),SY(5)
      COMMON/CHGS/PVCHG(5),XFCHG(2),SPXCHG(2),QVCHG(5),CSTCHG
      CSTCHG=100*(SCOST-BCOST)/BCOST
      WRITE(4,1)NUM,CSTCHG
    1 FORMAT(1H ,/,/,/,1H ,'THE PERCENT CHANGE IN COSTS FOR SCHEME',I3,
     1                2X,'=',F8.3)
      WRITE(4,10)
   10 FORMAT(1H ,/)
      DO 100 I=1,NV
      QVCHG(I)=100*(SY(I)-BY(I))/BY(I)
      PVCHG(I)=100*(SUBPV(I)-PV(I))/PV(I)
      WRITE(4,2)I,PVCHG(I)
    2 FORMAT(1H ,/,1H ,'THE PERCENT CHANGE IN VARIABLE INPUT PRICE',I2,
     1                    2X,'=',F8.3)
      WRITE(4,3)I,QVCHG(I)
    3 FORMAT(1H ,'THE PERCENT CHANGE IN VARIABLE INPUT QUANTITY',
     1                  I2,2X,'=',F9.3)
  100 CONTINUE
      WRITE(4,10)
      IF(NF.EQ.0)GO TO 201
      DO 200 I=1,NF
      XFCHG(I)=100*(SUBXF(I)-XF(I))/XF(I)
      IF(BW(I).LT..00001 .AND. BW(I).GT. -.00001)GO TO 150
      SPXCHG(I)=100*(SW(I)-BW(I))/BW(I)
      WRITE(4,4)I,SPXCHG(I)
    4 FORMAT(1H ,/,1H ,'THE PERCENT CHANGE IN FIXED INPUT SHADOW PRICE',
     1                  I2,2X,'=',F8.3)
      GO TO 160
  150 WRITE(4,6)
    6 FORMAT(1H ,/,1H ,'PERCENT CHANGE IN FIXED INPUT SHADOW PRICE ',
     1                   'UNDEFINED')
  160 CONTINUE
      WRITE(4,5)I,XFCHG(I)
    5 FORMAT(1H ,'THE PERCENT CHANGE IN FIXED INPUT QUANTITY',
     1                  I2,2X,'=',F9.3)
  200 CONTINUE
  201 CONTINUE
      RETURN
      END

      SUBROUTINE DWLC(NV,NF)
      COMMON/SUBIND/JSUBV,JSUBF
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/SUBPQS/SUBPV(5),SUBXF(2),SW(2),SY(5)
      COMMON/DWINF/SVRCST,SFXCST,SOCCST,SUBCST,DWL,DWLPB,DWLPVC,DWLPQ,
     1             BFSC
```

```
      COMMON/BEN/BNFTS
      COMMON/QUANT/Q
C*********************************************************************
C               COMPUTE DEADWEIGHT LOSS TOTAL & PERCENTS
C*********************************************************************
      SVRCST=0.
      DO 100 I=1,NV
      SVRCST=SVRCST+PV(I)*SY(I)
 100  CONTINUE
      SFXCST=0
      IF(NF.EQ.0)GO TO 201
      DO 200 I=1,NF
      SFXCST= SFXCST + PF(I)*SUBXF(I)
 200  CONTINUE
 201  CONTINUE
      SOCCST=SVRCST+SFXCST
      SUBCST=SOCCST-BCOST-BFXCST
      DWL=SUBCST
      BFSC=BNFTS/(BNFTS+DWL)
      DWLPB=DWL/BNFTS
      DWLPVC=DWL/BCOST
      DWLPQ=DWL/Q
      CALL DWLOUT
      IF(JSUBF.GT.0)CALL DWLFX(JSUBF,NV,NF)
      RETURN
      END


      SUBROUTINE DWLOUT
      COMMON/DWINF/SVRCST,SFXCST,SOCCST,SUBCST,DWL,DWLPB,DWLPVC,DWLPQ,
     1              BFSC
      COMMON/BEN/BNFTS
      WRITE(4,1)DWL,BNFTS,BFSC,DWLPB,DWLPVC,DWLPQ
 1    FORMAT(1H ,/,/,/,1H ,'DEADWEIGHT LOSS FROM THE SUBSIDY=',F12.2,/,
     1              1H ,33HFIRM'S BENEFITS FROM THE SUBSIDY=,F12.2,/,/,
     2               1H ,'BENEFITS AS A FRACTION OF SUBSIDY COST:',F9.3,
     3             /,1H ,'DEADWEIGHT LOSS AS FRACTION OF BENEFITS:',F8.3,
     4             /,1H ,'DEADWEIGHT LOSS AS FRACTION OF FIRM COSTS:',
     5            F6.3,/,1H ,'DEADWEIGHT LOSS AS FRACTION OF OUTPUT:    ',
     6            F6.3)
      RETURN
      END


      SUBROUTINE DWLFX(JSUBF,NV,NF)
      COMMON/DWINF/SVRCST,SFXCST,SOCCST,SUBCST,DWL,DWLPB,DWLPVC,DWLPQ,
     1              BFSC
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/SUBPQS/SUBPV(5),SUBXF(2),SW(2),SY(5)
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/BEN/BNFTS
      WRITE(4,1)
```

```
  1   FORMAT(1H ,/,1H ,'     DEADWEIGHT LOSS RELIES ON INITIAL SOCIAL',
     2' PRICES.',/,1H ,'     SOCIAL PRICES OF FIXED INPUTS CAN BE HARD',
     1 '  TO JUDGE.',/,1H ,'     ALTERNATIVE MEASURES OF DEADWEIGHT ',
     2       'LOSS CAN BE USEFUL.',/,1H ,'      SOME FOLLOW.')
      SHFXV=0
      SHSFXV=0
      DO 100 I=1,NF
      SHFXV=SHFXV+BW(I)*XF(I)
      SHSFXV=SHSFXV+BW(I)*SUBXF(I)
 100  CONTINUE
      ADWL=SVRCST+SHSFXV-BCOST-SHFXV
      WRITE(4,2)BFXCST,SFXCST,SHFXV,SHSFXV
  2   FORMAT(1H ,/,/,1H ,'INITIAL FIXED COSTS AT SOCIAL PRICES=  ',
     1        F12.2,/,1H ,'SUBSIDIZED FIXED COSTS AT SOCIAL PRICES=',
     2      F9.2,/,/,1H ,'FIXED COSTS AT INITIAL SHADOW PRICES=   ',
     3        F9.2,/,1H ,'SUBSIDIZED FIXED COSTS AT INITIAL SHADOW ',
     4        'PRICES =',F9.2)
      WRITE(4,3)ADWL
  3   FORMAT(1H ,/,/,1H ,'DEADWEIGHT LOSS IF INITIAL SHADOW PRICES ',
     1                   'ARE TRUE SOCIAL PRICES=',F9.3)
      JF=JSUBF
      IF(JF.EQ.3)GO TO 200
      FPRT=0
      CALL APF(JF,FPRT)
      GO TO 250
200   CONTINUE
      WRITE(4,4)
  4   FORMAT(1H ,/1H ,'  FOLLOWING EACH ASSUME OTHER INITIAL SOCIAL ',
     1               'FIXED INPUT PRICE CORRECT')
      DO 225 I=1,2
      JF=I
      JX=ABS(I-3)
      FPRT=PF(JX)*(SUBXF(JX)-XF(JX))
      CALL APF(JF,FPRT)
 225  CONTINUE
 250  CONTINUE
      RETURN
      END

      SUBROUTINE APF(JF,FPRT)
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/SUBPQS/SUBPV(5),SUBXF(2),SW(2),SY(5)
      COMMON/DWINF/SVRCST,SFXCST,SOCCST,SUBCST,DWL,DWLPB,DWLPVC,DWLPQ,
     1             BFSC
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/BEN/BNFTS
      APFX=-(SVRCST+FPRT-BCOST)/(SUBXF(JF)-XF(J))
      WRITE(4,4)JF,APFX
  4   FORMAT(1H ,/,1H ,'PRICE OF SUBSIDIZED FIXED INPUT',I2,' THAT',
     1              ' WOULD YIELD ZERO DWL=',F9.3)
      APFXCH=100.*(APFX-PF(JF))/PF(JF)
      WRITE(4,5)APFXCH
  5   FORMAT(1H ,'PERCENT CHANGE IN THE INITIAL SOCIAL PRICE TO ',
     1              'YIELD ZERO DWL=',F9.3)
```

```
      IF(BW(JF).LT. .00001 .AND. BW(JF) .GT. -.00001)GO TO 10
      AWFXCH=100.*(APFX-BW(JF))/BW(JF)
      WRITE(4,6)AWFXCH
 6    FORMAT(1H ,'PERCENT CHANGE IN THE INITIAL SHADOW PRICE TO ',
     1             'YIELD ZERO DWL=',F9.3)
 10   CONTINUE
      RETURN
      END



      SUBROUTINE GIFCHK(NV,NF,ICALL,IG,SUBPVL,SUBPVH)
      COMMON/BEN/BNFTS
      COMMON/QUANT/Q
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1             ,SMSHEL(2)
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/SUBPQS/SUBPV(5),SUBXF(2),SW(2),SY(5)
      COMMON/SUBPQ2/SSUBPV(5),SSUBXF(2),SSW(2),SSY(5)
      COMMON/ICHKR/JCHQ(5)
      COMMON/CHKR/CHQ(5)
      IG=0
C*************************************************************************
C                       SET  PRICE LEVELS TO
C                     CHECK FOR GIFFEN PROBLEM
C                   IN BASIC VALUE APPLICATION OR
C                    SUBSIDY OUTCOME APPLICATION
C*************************************************************************
      IF (ICALL.GE.0)GO TO 2900
      DO 2000 I=1,NV
      SSUBPV(I)=PV(I)
 2000 CONTINUE
      IF(NF.EQ.0)GO TO 2700
      DO 2500 I=1,NF
      SSUBXF(I)=XF(I)
 2500 CONTINUE
 2700 CONTINUE
      GO TO 3200
 2900 DO 3000 I=1,NV
      SSUBPV(I)=SUBPV(I)
3000  CONTINUE
      IF(NF.EQ.0)GO TO 3200
      DO 3100 J=1,NF
      SSUBXF(J)=SUBXF(J)
3100  CONTINUE
C**************************************************************************
C                  EXAMINE SLOPE OF DEMAND FOR GIFFEN EFFECT
C                       IMPOSE ZERO SLOPE IF POSITIVE
C**************************************************************************
3200  CALL GIFSET(NV,NF,ICHQ)
      IF(ICHQ.EQ.0)RETURN
      IF(ICALL.EQ.0)GO TO 3600
```

```
      IF(ICALL.EQ.-1)GO TO 4000
      IND=ICALL
      IF(JCHQ(IND).EQ.O)RETURN
      SSUBPV(IND)=.25*SUBPV(IND)+.75*SUBPVH
 3210 CALL GIFSET(NV,NF,ICHQ)
      HALT=CHQ(IND)*SSCOST/(SSUBPV(IND)**2)
      AHALT=ABS(HALT)
      IF(AHALT.LT. .0001)GO TO 3250
      IF(HALT.LT.O) SSUBPV(IND)=(SSUBPV(IND)+SUBPV(IND))*.5
      IF(HALT.GT.O) SSUBPV(IND)=(SSUBPV(IND)+SUBPVH)*.5
      GO TO 3210
C*******************************************************************
C               IF SLOPE POSITIVE ONLY AT PRICES
C                LOWER THAN NEEDED FOR BENEFITS
C                    RESUME BINARY SEARCH;
C                  OTHERWISE IMPOSE ZERO SLOPE
C                   AND SET SUBSIDIZED PRICE
C                  AS NEEDED FOR BENEFITS OR
C                   CALCULATE BENEFITS AS
C                    SCHEME REQUIRES
C*******************************************************************
 3250 TESTP=PV(IND)-BNFTS/SSY(IND)
      IF (TESTP.GT.SSUBPV(IND)) SUBPV(IND)=SSUBPV(IND)
      IF (TESTP.GT.SSUBPV(IND))RETURN
      IG=1
      SUBPV(IND)=TESTP
      DO 3300 I=1,NV
 3300 SY(I)=SSY(I)
      IF(NF.EQ.O)GO TO 3360
      DO 3350 J=1,NF
 3350 SW(J)=SSW(J)
 3360 CONTINUE
      GIFPV=SSUBPV(IND)
      CALL GIFOUT(NV,NF,GIFPV)
      RETURN
C*******************************************************************
C                    TREAT CASE OF SCHEME GIVEN BY USER
C*******************************************************************
 3600 CONTINUE
      IF(ICHQ.GT.1)RETURN
      DO 3700 I=1,NV
      IF (JCHQ(I).EQ.1)IND=I
 3700 CONTINUE
      SSUBPV(IND)=.50*SUBPV(IND)+.50*PV(IND)
 3710 CALL GIFSET(NV,NF,ICHQ)
      HALT=CHQ(IND)*SSCOST/(SSUBPV(IND)**2)
      AHALT=ABS(HALT)
      IF(AHALT.LT. .0001)GO TO 3750
      IF(HALT.LT.O) SSUBPV(IND)=(SSUBPV(IND)+SUBPV(IND))*.5
      IF(HALT.GT.O) SSUBPV(IND)=(SSUBPV(IND)+PV(IND))*.5
      GO TO 3710
 3750 BNFTS=BCOST-SSCOST-(SSUBPV(IND)-SUBPV(IND))*SSY(IND)

      WRITE(4,16)BNFTS
```

```
 16  FORMAT(1HO,/,/,/,1H ,'         BENEFITS=',F12.2,2X,'IN SCHEME')

     WRITE(4,98)
 98  FORMAT(1H ,/,/,/,/,
    1    '                 THESE BENEFITS ARE FROM THE',/,1H ,
    2    '                 FOLLOWING SUBSIDY SCHEME')
     WRITE(4,97)
 97  FORMAT(1H ,/)
     DO 30 I=1,NV
     WRITE(4,9)I,SUBPV(I)
  9  FORMAT(1H ,/,1H ,'SUBSIDIZED PRICE FOR VARIABLE INPUT',I2,1X,
    1         '=',F12.2)
 30  CONTINUE
     IF(NF.EQ.0)GO TO 41
     DO 40 I=1,NF
     WRITE(4,99)I,SUBXF(I)
 99  FORMAT(1H ,/,1H ,'SUBSIDIZED QUANTITY FOR FIXED INPUT',I2,1X,'=',
    1            F12.2)
 40  CONTINUE
 41  CONTINUE

     DO 3800 I=1,NV
3800 SY(I)=SSY(I)
     IF(NF.EQ.0)GO TO 3860
     DO 3850 J=1,NF
3850 SW(J)=SSW(J)
3860 CONTINUE
     GIFPV=SSUBPV(IND)
     CALL GIFOUT(NV,NF,GIFPV)
     IG=1
     RETURN
C***********************************************************************
C                    TREAT CASE OF BASIC VALUE COMPUTATION
C***********************************************************************
4000 CONTINUE
     IG=1
     IF(ICHQ.GT.1)IG=2
     IF(ICHQ.GT.1)RETURN
     DO 4100 I=1,NV
     IF (JCHQ(I).EQ.1)IND=I
4100  CONTINUE
     SUBPVH=1000*PV(IND)
     SSUBPV(IND)= 10*PV(I)
4200  CALL GIFSET(NV,NF,ICHQ)
     HALT=CHQ(IND)*SSCOST/(SSUBPV(IND)**2)
     AHALT=ABS(HALT)
     IF(AHALT.LT. .0001)GO TO 4500
     IF(HALT.LT.0) SSUBPV(IND)=(SSUBPV(IND)+PV(IND))*.5
     IF(HALT.GT.0) SSUBPV(IND)=(SSUBPV(IND)+SUBPVH)*.5
     GO TO 4200
4500 WRITE(4,5000)IND,SSUBPV(IND)
5000 FORMAT(1H ,/,1H ,'VARIABLE INPUT ',I1,' TURNED GIFFEN AT PRICE=',
    1     F12.3)
     DO 5100 I=1,NV
```

```
      BY(I)=SSY(I)
 5100 CONTINUE
      IF(NF.EQ.0)GO TO 5300
      DO 5200 J=1,NF
      BW(J)=SSW(J)
 5200 CONTINUE
 5300 CONTINUE
      RETURN
      END


      SUBROUTINE GIFSET(NV,NF,ICHQ)
      COMMON/BEN/BNFTS
      COMMON/QUANT/Q
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1              ,SMSHEL(2)
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/SUBPQS/SUBPV(5),SUBXF(2),SW(2),SY(5)
      COMMON/SUBPQ2/SSUBPV(5),SSUBXF(2),SSW(2),SSY(5),SSCOST
      COMMON/ICHKR/JCHQ(5)
      COMMON/CHKR/CHQ(5)
C***********************************************************************
C                     INITIALIZE ELEMENTS OF
C                        SUBSIDIZED COSTS
C***********************************************************************
      SUMLV1=0.0
      SUMLF1=0.0
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      SUM4=0.0
      SUM5=0.0
C***********************************************************************
C                       COMPUTE ELEMENTS OF
C                        SUBSIDIZED COSTS
C***********************************************************************
      DO 200 I=1,NV
      SUMLV1=SUMLV1+A(I)*LOG(SSUBPV(I))
      DO 100 J=1,NV
 100  SUM1=SUM1+.5*AVV(I,J)*LOG(SSUBPV(I))*LOG(SSUBPV(J))
      IF(NF.EQ.0)GO TO 151
      DO 150 K=1,NF
      SUM2=SUM2+GVF(I,K)*LOG(SSUBPV(I))*LOG(SSUBXF(K))
 150  CONTINUE
 151  CONTINUE
      SUM3=SUM3+TVQ(I)*LOG(SSUBPV(I))*LOG(Q)
 200  CONTINUE
      IF(NF.EQ.0)GO TO 401
      DO 400 I=1,NF
      SUMLF1=SUMLF1+H(I)*LOG(SSUBXF(I))
      DO 300 J=1,NF
 300  SUM4=SUM4+.5*BFF(I,J)*LOG(SSUBXF(I))*LOG(SSUBXF(J))
```

```
      SUM5=SUM5+THFQ(I)*LOG(SSUBXF(I))*LOG(Q)
  400 CONTINUE
  401 CONTINUE
C**********************************************************************
C                         COMPUTE LOG COST & COST
C                              UNDER SUBSIDY
C**********************************************************************
      SLGCST=SUM1+SUM2+SUM3+SUM4+SUM5+SUMLV1+SUMLF1+BASE+ZQ*LOG(Q)
      SSCOST=EXP(SLGCST)
C***********************************************************************
C                         COMPUTE SUBSIDIZED DEMANDS
C**********************************************************************
 4000 DO 900 I=1,NV
      SSUM1=0.0
      SSUM2=0.0
      DO 500 J=1,NV
  500 SSUM1=SSUM1+AVV(I,J)*LOG(SSUBPV(J))
      IF(NF.EQ.0)GO TO 601
      DO 600 K=1,NF
      SSUM2=SSUM2+GVF(I,K)*LOG(SSUBXF(K))
  600 CONTINUE
  601 CONTINUE
      SSY(I)=(SSCOST/SSUBPV(I))*(A(I)+SSUM1+SSUM2+TVQ(I)*LOG(Q))
  900 CONTINUE
      IF(NF.EQ.0)GO TO 1001
C**********************************************************************
C                       COMPUTE SUBSIDIZED SHADOW PRICES
C**********************************************************************
      DO 1000 I=1,NF
      SSSUM1=0.0
      SSSUM2=0.0
      DO 800 J=1,NV
  800 SSSUM1=SSSUM1+GVF(J,I)*LOG(SSUBPV(J))
      DO 950 K=1,NF
  950 SSSUM2=SSSUM2+BFF(I,K)*LOG(SSUBXF(K))
      SSW(I)=-1.*(SSCOST/SSUBXF(I))*(H(I)+SSSUM1+SSSUM2+THFQ(I)*LOG(Q))
 1000 CONTINUE
 1001 CONTINUE
C***********************************************************************
C
C                          CHECK FOR UPWARD SLOPING
C                              FACTOR DEMANDS
C
C***********************************************************************
      ICHQ=0
      DO 2000 I=1,NV
      JCHQ(I)=0
      SHTRM=(SSUBPV(I)*SSY(I)/SSCOST)*((SSUBPV(I)*SSY(I)/SSCOST)-1)
      CHQ(I)=AVV(I,I)+SHTRM
      IF(CHQ(I).GT.0)ICHQ=ICHQ+1
      IF(CHQ(I).GT.0)JCHQ(I)=1
 2000 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE GIFOUT(NV,NF,GIFPV)
      COMMON/BEN/BNFTS
      COMMON/QUANT/Q
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/SUBPQ2/SSUBPV(5),SSUBXF(2),SSW(2),SSY(5),SSCOST
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1                  ,SMSHEL(2)
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/SUBPQS/SUBPV(5),SUBXF(2),SW(2),SY(5)
      WRITE(4,2000)GIFPV
2000  FORMAT(1H ,/,1H ,'           SUBSIDIZED GOOD TURNED',/,1H ,
     1               '           GIFFEN AT PRICE=',F12.3)

C*********************************************************************
C                        REPORT SUBSIDIZED DEMANDS
C*********************************************************************
      DO 900 I=1,NV
      WRITE(4,602)I,SUBPV(I),SY(I)
  602 FORMAT(1H ,/1H ,'SUBSIDIZED PRICE FOR VARIABLE INPUT',I2,2X,'=',
     1   F12.2,/,1H ,'SUBSIDIZED QUANTITY OF THAT VARIABLE INPUT =',
     2   F12.3)
  900 CONTINUE
      IF(NF.EQ.O)GO TO 1001
C*********************************************************************
C                      REPORT SUBSIDIZED SHADOW PRICES
C*********************************************************************
      DO 1000 I=1,NF
      WRITE(4,701)I,SW(I),SUBXF(I)
  701 FORMAT(1H ,/1H ,'SUBSIDIZED SHADOW PRICE OF FIXED INPUT',I2,2X,
     1'=',F12.3,/,1H ,'SUBSIDIZED QUANTITY OF THAT FIXED INPUT =',
     2    F12.3)
1000  CONTINUE
1001  CONTINUE
      RETURN
      END

      SUBROUTINE TECH
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1    ,SMSHEL(2)
      WRITE(4,1)BASE,A(1),A(2),A(3),A(4),A(5)
    1 FORMAT(1H ,/,/,1H ,'BASE=',F12.5,/,1H ,'A1=',F8.4,' A2=',F8.3,
     1                 ' A3=',F8.3,' A4=',F8.3,' A5=',F8.3)
      WRITE(4,2)ZQ,H(1),H(2)
    2 FORMAT(1H ,'QCOEF=',F11.5,/,1H ,'H1=',F8.4,' H2=',F8.3)
      WRITE(4,3)AVV(1,1),AVV(2,2),AVV(3,3),AVV(4,4),AVV(5,5),
     1             AVV(1,2),AVV(1,3),AVV(1,4),AVV(1,5),
     2             AVV(2,3),AVV(2,4),AVV(2,5),
     3             AVV(3,4),AVV(3,5),
     4             AVV(4,5)
    3 FORMAT(1H ,/,1H ,'AVV11=',F8.3,' AVV22=',F8.3,' AVV33=',F8.3,/,
```

```
     1             1H ,'AVV44=',F8.3,' AVV55=',F8.3,/,1H ,
     2      'AVV12=',F8.3,' AVV13=',F8.3,' AVV14=',F8.3,' AVV15=',F8.3,
     3            /,1H ,'AVV23=',F8.3,' AVV24=',F8.3,' AVV25=',F8.3,
     4            /,1H ,'AVV34=',F8.3,' AVV35=',F8.3,
     5            /,1H ,'AVV45=',F8.3)
      WRITE(4,4)BFF(1,1),BFF(2,2),
     1          BFF(1,2)
   4  FORMAT(1H ,/,1H ,'BFF11=',F8.3,' BFF22=',F8.3,/,
     4            /,1H ,'BFF12=',F8.3)
      WRITE(4,5)GVF(1,1),GVF(1,2),
     1          GVF(2,1),GVF(2,2),
     2          GVF(3,1),GVF(3,2),
     3          GVF(4,1),GVF(4,2),
     4          GVF(5,1),GVF(5,2)
   5  FORMAT(1H ,/,1H ,'GVF11=',F8.3,' GVF12=',F8.3,/,
     1             1H ,
     2      'GVF21=',F8.3,' GVF22=',F8.3,
     3            /,1H ,'GVF31=',F8.3,' GVF32=',F8.3,
     4            /,1H ,'GVF41=',F8.3,' GVF42=',F8.3,
     5            /,1H ,'GVF51=',F8.3,' GVF52=',F8.3)
      WRITE(4,6)TVQ(1),TVQ(2),TVQ(3),TVQ(4),TVQ(5)
   6  FORMAT(1H ,'T1=',F8.4,' T2=',F8.3,
     1                ' T3=',F8.3,' T4=',F8.3,' T5=',F8.3)
      WRITE(4,7)THFQ(1),THFQ(2)
   7  FORMAT(1H ,'THFQ1=',F8.4,' THFQ2=',F8.3,
     1                ' THFQ3=',F8.3)
      RETURN
      END

      SUBROUTINE TECSET(NV,NF)
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/ELASS/ESOREL(5,5),ELASVV(5,5),ELASVF(5,2)
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1                ,SMSHEL(2)
      WRITE(6,10)
  10  FORMAT(1HO,/,'TYPE BASE COST AGAIN. REMEMBER TO USE DECIMAL',
     1           /,1H ,' INPUTS UNLESS TOLD OTHERWISE')
      READ(5,11)BASE
  11  FORMAT(F12.3)
      WRITE(6,12)
  12  FORMAT(1HO,'IF YOU WANT TO CHANGE VARIABLE FACTOR SHARES TYPE 1;',
     1     /,1H ,'OTHERWISE TYPE O')
      READ(5,13)INDEX
  13  FORMAT(I1)
      IF(INDEX.EQ.O)GO TO 100
      DO 50 I=1,NV
      WRITE(6,14)I
  14  FORMAT(1HO,/,'IF YOU WANT TO CHANGE THE SHARE OF VARIABLE INPUT',
     1    I2,' TYPE 1;',/,1H ,'OTHERWISE TYPE O')
      READ(5,13)INDEX
      IF(INDEX.EQ.1)WRITE(6,2)I
      IF(INDEX.EQ.1)WRITE(4,2)I
   2  FORMAT(1HO,'TYPE THE FACTOR SHARE OF VARIABLE INPUT',I2)
      IF(INDEX.EQ.1)READ(5,11)SHR(I)
```

```
      IF(INDEX.EQ.1)WRITE(4,11)SHR(I)
 50   CONTINUE
100   CONTINUE
      WRITE(6,15)
 15   FORMAT(1HO,'IF YOU WANT TO CHANGE ELASTICITIES OF SUBSTITUTION',
     1      /,1H ,'AMONG VARIABLE INPUTS, TYPE 1; OTHERWISE TYPE O')
      READ(5,13)INDEX
      IF(INDEX.EQ.O)GO TO 200
      NVM1=NV-1
      DO 175 I=1,NVM1
      WRITE(6,16)I
 16   FORMAT(1HO,'IF YOU WANT TO CHANGE AN ELASTICITY',
     1 /,1H ,'OF SUBSTITUTION FOR VARIABLE INPUT',I2,' TYPE 1;',
     2    /,1H ,'OTHERWISE TYPE O')
      READ(5,13)INDEX
      IF(INDEX.EQ.O)GO TO 175
      K=I+1
      DO 150 J=K,NV
      WRITE(6,17)I,J
      WRITE(4,17)I,J
 17   FORMAT(1HO,'TYPE THE ELASTICITY OF SUBSTITUTION FOR',
     1 /,1H , 'VARIABLE INPUTS', I2,' AND',I2)
      READ(5,11)ELASVV(I,J)
      WRITE(4,11)ELASVV(I,J)
150   CONTINUE
175   CONTINUE
200   CONTINUE
      WRITE(6,7)
  7   FORMAT(1HO,'IF YOU WANT TO CHANGE ELASTICITIES AMONG FIXED',
     1      /,1H ,'AND VARIABLE INPUTS, TYPE 1; OTHERWISE TYPE O')
      READ(5,13)INDEX
      IF(INDEX.EQ.O)GO TO 300
      DO 275 I=1,NV
      WRITE(6,18)I
 18   FORMAT(1HO,'IF YOU WANT TO CHANGE AN ELASTICITY',
     1 /,1H ,'OF A FIXED INPUT WITH VARIABLE INPUT',I2,' TYPE 1;',
     2    /,1H ,'OTHERWISE TYPE O')
      READ(5,13)INDEX
      IF(INDEX.EQ.O)GO TO 275
      DO 250 J=1,NF
      WRITE(6,19)I,J
      WRITE(4,19)I,J
 19   FORMAT(1HO,'TYPE THE ELASTICITY OF DEMAND FOR VARIABLE INPUT',I2,
     1 /,1H , 'WITH RESPECT TO FIXED INPUT', I2)
      READ(5,11)ELASVF(I,J)
      WRITE(4,11)ELASVF(I,J)
250   CONTINUE
275   CONTINUE
300   CONTINUE
      CALL SETPAR(NV,NF)
      RETURN
      END
```

```
      SUBROUTINE CHECK
      COMMON/QUANT/Q
      COMMON/PSNQS/PV(5),PF(2),SHR(5),XF(2),BFFO(3),FQO(2),HO(2),ZQ
      COMMON/ELASS/ESOREL(5,5),ELASVV(5,5),ELASVF(5,2)
      COMMON/CS/BASE,A(5),H(2),AVV(5,5),GVF(5,2),BFF(2,2),TVQ(5),THFQ(2)
     1    ,SMSHEL(2)
 2    FORMAT(1H ,/,1H ,'I=',1I1,2X,'PV(I)=',F8.2,2X,'SHR(I)=',F5.2,2X,
     1               'TVQ(I)=',F8.2,2X,'AI=',F8.2)
 3    FORMAT(1H ,/,1H ,'I=',I1,2X,'J=',I1,2X,'ESOREL(IJ)=',F12.2,2X,
     1        'ELASVV(IJ)=',F12.2,2X,/,5H      ,'AVV(IJ)=',F12.2)
 4    FORMAT(1H ,/,1H ,'I=',I1,2X,'J=',I1,2X,'GVF(IJ)=',F12.2,2X,
     1        'ELASVF(IJ)=',F12.2)
 5    FORMAT(1H ,/,1H ,'I=',I1,2X,'BFFO(I)=',F12.2)
 6    FORMAT(1H ,/,1H ,'I=',I1,2X,'XF(I)=',F12.2,2X,
     1        'FQO(I)=',F12.2,2X,'THFQ(I)=',F12.2)
      WRITE(4,13)ZQ
 13   FORMAT(1H ,/,1H ,'     ZQ=',F8.3)

      DO 400 I=1,5
      WRITE(4,2)I,PV(I),SHR(I),TVQ(I),A(I)
      DO 44 J=1,5
      WRITE(4,3)I,J,ESOREL(I,J),ELASVV(I,J),AVV(I,J)
 44   CONTINUE
      DO 45 J=1,2
      WRITE(4,4)I,J,GVF(I,J),ELASVF(I,J)
      IF(I.GE.3) GO TO 45
C     WRITE(6,7)I,J,BFF(I,J)
 7    FORMAT(1H ,/,'I=',I1,2X,'J=',I1,2X,'BFF(IJ)=',F12.8)
      WRITE(4,7)I,J,BFF(I,J)
 45   CONTINUE
      IF(I.GE.3)GO TO 400
      WRITE(4,5)I,BFFO(I)
      WRITE(4,6)I,XF(I),FQO(I),THFQ(I)
      WRITE(4,99)I,H(I)
 99   FORMAT(1H ,/,1H ,'HI FOR FIXED INPUT',I3,2X,'=',F12.3)
 400  CONTINUE
      RETURN
      END

      SUBROUTINE CHECK2
      COMMON/BSVL/BY(5),BW(2),BCOST,SCOST,BFXCST
      COMMON/BEN/BNFTS
      WRITE(4,1)BNFTS,BCOST,SCOST,BFXCST
 1    FORMAT(1H ,/1H ,'BENEFITS=',F12.3,/,1H ,'BCOST=',F12.3,/,1H ,
     1               'BFXCST=',F12.3)
      DO 100 I=1,5
 100  WRITE(4,2)I,BY(I)
 2    FORMAT(1H ,/1H ,'INITIAL DEMAND FOR VARIABLE INPUT',I2,2X,'=',
     1            F12.3)
      DO 200 J=1,2
 200  WRITE(4,3)J,BW(J)
```

```
3  FORMAT(1H ,/1H ,'INITIAL SHADOW VALUE OF FIXED INPUT',I2,2X,'=',
  1               F12.3)
   RETURN
   END
```

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