The Male and Female Employment Effect of Compensation in Korea's Manufacturing Industry: Gender Differences in the Workplace

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Abstract

This paper reports a study on the demand for male and female workers in Korea's manufacturing industry. The labor-output elasticities were estimated using annual time-series data (1972-1989) for durable and non-durable manufacturing. We found that the potential for substitution among male production, female production, and office workers is severely restricted. This is because of the rigid institutional factors in educationally and culturally based work rules. On the flip side, this suggests that the firm's ability to shift work tasks between genders or between job classifications is also restricted significantly. A finding like this, for example, can serve as a useful message from which developing countries can learn how to improve the usage of their female workers.[1]

1. *Introduction*

Between 1970 and 1990, Korea's real GNP growth rate was 8.7 percent per annum. The manufacturing sector propelled overall growth with an annual growth rate of 16.8 percent. By 1989, manufacturing's employment share reached 27.6 percent. The reason for Korea's economic success has been widely studied [e.g., Amsden (1992) references about 200 English language studies in her bibliography]. Korean trade policies, export-oriented growth strategy and sources of output demand have been studied. Its economic planning and implementation apparatuses and industrial organization have been analyzed; and relative factor contributions to output growth have been examined.

However, comparatively few studies have analyzed the structure of input factor demand in Korea's manufacturing sector. As we know of, this paper is first to apply the well-known dynamic factor demand model (Treadway, 1974; Berndt and et al., 1979; Denny and et al., 1980) to analyze variable and quasi-fixed inputs in Korean manufacturing. With annual time-series data (1972-1989) for durable and non-durable manufacturing, both the short-run and long-run input demand parameters and associated elasticities are estimated; and the speed of adjustment of the quasi-fixed input as an endogenous, non-constant parameter is also estimated. Our treatment of the labor input is also unique: male and female hours worked enter the analysis as distinct inputs.

Based on the estimates of own-price, input substitution and output elasticities, we demonstrate that the structure of manufacturing demand for inputs in the durable and non-durable sub-sectors are significantly different; and further, within these levels of sectorial disaggregation, we show the structure of manufacturing demand for male and female labor inputs are also different and in fact balkanized based on worker classification and gender. It is also one of our salient findings that the estimated inter-labor substitution elasticities provide evidence for limiting the firm's ability to shift work tasks between job classifications and genders in response to relative wage changes without significantly incrementing production costs, and besides, these elasticity estimates suggest that the firm's ability to maintain short-run output levels by transferring job tasks may be seriously limited in cases of work

[1] The authors would like to thank Mario F. Bognanno, Professor Emeritus, for his contribution to this research. He provided us valuable counselling and encouragement.

stoppages by any single class of workers. We believe that these are significant findings for policy makers in developing countries.

Section 2 concisely presents the model to derive input demand and elasticity. In section 3, we discuss our results highlighting male-female demand differences and the relationship between output and inputs in Korean manufacturing. Finally, section 4 presents a summary of salient findings and relevant policy-related conclusions. Appendix contains a detailed description of model and estimation process, definitions of industries and the variables, and estimates of labor demand functions.

2. *Labor Demand Model and Estimation*

To motivate our condensed version of the formal model, visualize a firm in long-run equilibrium. By assumption, this firm uses prevailing technology, to produce at some exogenously determined level of output, per unit of time. Further, it employs the combination of various inputs, including male labor (M)[2], female labor (F), energy (E) and capital stock (K), each paid at its market-determined unit price (W_M, W_F, W_K, and W_E) that minimizes production costs. To convert this basic model to a model of dynamic optimization, additionally assume that capital stock (K) is quasi-fixed, and that the firm is a multi-period cost minimizer. In brief, this is the model of dynamic factor demand developed by Berndt and et al. (1979). We estimated this model-based input demand functions and then calculated the own-price [η_{ii}], input substitution [σ_{ij}] and output elasticities [η_{iQ}]. The estimation procedure of input demand functions, data used for estimation, and estimates of demand functions are described in Appendix.

3. *Empirical Results*

All variables are measured annually, and their own-price/cross-price, substitution, and output/technology elasticities are estimated and presented in Tables 1, 2, and 3, respectively. Energy's implicit own-price parameters are positive in durable and negative in non-durable manufacturing, but insignificant in both cases. We can account

Table 1: Price Elasticity Estimates: Durable and Non-durable Manufacturing, 1972-1989

	Durable		Non-Durable		Aggregate	
	Short run	Long run	Short run	Long run	Short Run	Long Run
η_{MM}	-.0415	-.0612	.0578	.0577	-.0130	-.0130
η_{FF}	.0271	.0218	-.0224	-.0227	.1947	.1946
η_{OO}	.0681	.0470	-.0434	-.0435	-.0924	-.0924
η_{KK}		-.0840	.0	-.0011	.0	-.0003
η_{MF}	.0213	.0162	-.1649	-.1650	-.2087	-.2087
η_{MO}	.0625	.0460	-.0063	-.0064	.0645	.0645
η_{MK}	.0	-.0866	.0	.0010	.0	.0004
η_{ME}	-.0423	.0856	.1134	.1132	.1570	.1571
η_{FM}	.0844	.0642	-.1709	-.1710	-.3596	-.3596
η_{FO}	-.0405	-.0574	.0374	.0372	-.1358	-.1358
η_{FK}	.0	-.0888	.0	.0020	.0	.0003
η_{FE}	-.0709	.0602	.1559	.1550	.3008	.3005
η_{OM}	.0963	.0710	-.0059	-.0060	.0768	.0768
η_{OF}	-.0158	-.0223	.0336	.0334	-.0938	-.0938
η_{OK}	.0	-.1115	.0	.0010	.0	-.0010
η_{OE}	-.1489	.0159	.0157	.0152	.1094	.1094
η_{KM}	.0	-.0191	.0	.0010	.0	.0010
η_{KF}	.0	-.0050	.0	.0020	.0	.0010
η_{KO}	.0	-.0160	.0	.0020	.0	-.0004
η_{KE}	.0	.1240	.0	.0073	.0	.0030

Note: All elasticities are evaluated at the sample mean for the period of 1972-1989 and are calculated as $(w_j/i)(\partial i/\partial w_j)$, where W_j is normalized price W_j/W_E for all inputs i, j = M, F, O, E and K; in the short run, η_{KK} is zero by definition.

[2] For the notations of variables, refer to A.3 in Appendix.

for the manufacturing's relative insensitivity to energy price (W_E) by our subsequent showing that manufacturing technology leaves little room for input substitutions, which include energy (fuel and electricity).

For the own-price, cross-price [η_{ij}], and substitution elasticities in both industrial sub-aggregates of durable and non-durable manufacturing, the absolute values of the short-run own-price elasticity of labor inputs are too small to be of great importance to policy manipulations is a striking feature (refer to Table 1). Recall that none of our own-price parameters was significantly different from zero; it appears that whether a given input's relative price increases or decreases, the demand response will be minimal, ceteris paribus. Moreover, the meager differences between the short-run and long-run employment elasticities appearing in Table 1 suggests that generally labor inputs are either very weak substitutes (positive elasticity of substitution) or complements (negative elasticity of substitution) for capital, even though all estimates of demand function parameters themselves are quite significant. As a result, the capital adjustments caused by an alteration in the relative price of male, female, and office workers minimally affect the optimum mix of labor inputs over the long-run at specific levels of output.[3]

Clearly, the negatively signed (but insignificant complements) own-price labor input elasticities in Table 1 are smaller in absolute value than those presented in other cost/production functions time-series studies based on manufacturing data from developed countries. Hamermesh (1986) catalogues a large number of these studies, but strict comparisons are attenuated because our specification of the labor inputs is not a replication of any of the studies he reviews. This same conclusion also applies to Kwon and Williams' (1982) study.

Lee (1977) argues that the *(secular) accumulation* of highly advanced technologies imported from abroad may have limited the potential for labor-capital substitutions in Korea's manufacturing. By inference, this argument helps to account for our small own-price elasticities. In fact, it fits our empirical results quite nicely. Consider first the labor-capital cross-price elasticity (η_{iK}) in Table 1. Our long-run η_{iK} estimates for durable manufacturing are: -0.0866, -0.0888, and -0.1115 for male production workers, female production workers, and office workers, respectively. All three labor-capital elasticities are quite significant but small in absolute value. Moreover, these estimates suggest that the labor inputs and capital for durable production are complements, *not* substitutes. Kwon and Williams (1982) also found evidence of labor-capital complementarity for some product groups. In the case of non-durable production, the same three estimates of elasticity are: 0.001, 0.002, and 0.001.

Thus, here we find statistically significant labor-capital substitutabilities--but again all three elasticities are quite small in magnitude.

Table 2: Substitution Elasticity Estimates: Durable and Non-durable Manufacturing Sectors, 1972-1989

	Durable	Non-durable	Aggregate
σ_{MF}	.9921	-1.455	-2.458
σ_{MO}	.4430	-.0513	.5247
σ_{FO}	-.5550	.2968	-1.107
σ_{MK}	-.1361	.0007	-.0000
σ_{FK}	-.1403	.0024	.0005
σ_{OK}	-.1795	.0014	-.0001
σ_{ME}	.6159	1.267	1.478
σ_{FE}	.4331	1.736	2.827
σ_{OE}	.1144	.1702	1.029
σ_{KE}	.8920	.0076	.0029

Note: The substitution elasticities are calculated as $\sigma_{ij} = \eta_{ij} / s_j$, where s_j is the cost share of input j.

In table 2, we recast these labor-capital cross-price elasticities as long-run elasticities of substitution. Particular attention is called to the non-durable sector's σ_{iK}, i = M, F, and O (male, female, and office workers). Even though these substitution estimates are significantly different from zero (Kim, 1984; Kwon and Williams, 1982),

[3] Relevant estimates of elasticity in Table 1 suggest that long-run capital is sensitive to own-price variations. The relevant estimates of cross-price elasticity and elasticity of substitution in Tables 1 and 2 further suggest that the own-price sensitivity is largely due to the potential to substitute capital for energy.

their order of magnitude (0.0007- 0.0014) would seem to limit the claim that ending capital subsidy policies or advancing wage subsidy policies will appreciably change the output-constant Labor/Capital ratio (L_i/K). This same argument holds with respect to contemporary concerns about the output-constant adverse employment effects of Korea's newly enacted wage augmenting collective bargaining and minimum wage policies.

Second, a related support for the above Lee's argument is also found in the top panel of Table 3. For all three samples, the (long-run) march of time is inversely related to M, F and O demands--a result compatible with the labor-saving technology argument. To illustrate, in the case of aggregate manufacturing the demand for male production workers, predominately male office workers[4], and female production workers has declined on average by 0.13 percent, 0.21 percent and 0.31 percent per year, respectively. The "job displacement" effects of time (technology) from the durable and non-durable sub-aggregate sectors also appear in Table 3. In both cases, the secular erosion in job opportunities has been most heavily felt in jobs typically held by females.

Table 3: Elasticity Estimates of Durable, Non-durable, and Aggregate Manufacturing, 1972-1989

	Durable		Non-durable		Aggregate	
	Short run	Long run	Short run	Long run	Short Run	Long Run
η_{MT}	-.2029	-.2620	.0485	-.0690	-.1342	-.1340
η_{FT}	-.3596	-.4202	.1085	-.2730	-.2674	-.3057
η_{OT}	-.1052	-.1813	.0578	-.1650	-.2167	-.2094
η_{KT}	.0	-.0574	.0	.2913	.0	.0523
η_{MQ}	.1566	1.2890	.8425	.3803	.8112	.8161
η_{FQ}	.5395	1.7010	1.8382	.2756	1.7994	.9276
η_{OQ}	-.0297	1.4282	1.5572	.6446	1.0992	1.2646
η_{KQ}	.0	1.0989	.0	1.1933	.0	1.1903

Note: η_{iT} is calculated as $\partial \ln i/\partial t$ for all i = M, F, O, and K.

A final explanation for the labor demands/own-price insensitivities is suggested by the pattern of input relationships appearing in Tables 1 and 2. Interestingly, we find that the potential for substitutions among the male, female and office workers is also very much limited as suggested. Among Table 1's long-run cross-price elasticities (η_{ij}, i, j = M, F, O and i ≠ j), only the symmetrical pairs M-O (durable), M-F (non-durable), and M-F and F-O (aggregate) are premised on parameters whose t-values exceed one at the very least. For these elasticities, only M and O in durable goods manufacturing are substitutes. The remaining pairs of labor inputs are either complements or (statistically) independent factors of production. Referring to Table 2, we see that where substitutability is present, the elasticities of substitution tend to be less than 0.50, but where labor inputs are complementary; the absolute values of the corresponding substitution elasticities are generally greater than unity. By inference, we interpret this pattern of inter-labor inputs' elasticities to mean that rigid institutional barriers (e.g., educationally or culturally based "work rules") may be limiting male-female (M-F) and "blue collar"-"white collar" (M/F-O) substitution possibilities further explaining our low labor input own-price elasticities.

As for the output elasticity, Morrison and Berndt (1981) have observed that one of the more salient findings in the empirical literature is that the short-run elasticity of demand for aggregate labor with respect to output (Q) is less than unity and less than the long-run elasticity. This finding directly contradicts the idea that if Q = g(L,K), where K is quasi-fixed and Q is monotonically increasing and concave in L and K, as Q increases L increases by proportionately more, thus η_{LQ}(s.r.) > 1, exhibiting diminishing returns to the variable input labor (L).

This apparent contradiction can be explained as "labor hoarding." That is, when there are substantially increasing marginal adjustment costs to rapid changes in L, the dynamic cost-minimizing firm treats L as quasi-fixed in the face of changes in Q demanded. Thus, the firm spreads adjustments to L's level over time, thereby causing short-run increasing returns (Morrison and Berndt, 1981). Within the context of our research, if η_{LQ}(s.r.) is smaller for O and M than F, hoarding may be present. This inference derives from the fact that a large share of female production workers in Korea's manufacturing sector leave the labor market after marriage (which occurs around age 27). Consequently, the economic incentive is for the firm to place female production workers in jobs

[4] Averaged over the sample period, males constitute approximately 80 percent of all office workers.

requiring smaller search, orientation and training outlays in order to reduce the adjustment costs attached to their more volatile employment levels relative to their male office and production worker counterparts. A similar inference would follow from a finding of stronger short-run increasing returns to office workers (i.e., "white collar" workers such as owners, managers, professionals, sales personnel and so forth) than for male production workers.[5]

However, this contradiction should also be amenable to an explanation by the pattern of interrelated input demands that our model is designed to isolate. For example, faced with a given increase in Q we expect the cost minimizer to increase L proportionately less than Q (in the short-run) when quasi-fixed K and L are long-run complements, and (assuming constant returns to scale) make-up for the short-run lag in L's increase by more than proportionately increasing the amount of some other long-run K-substitute input like E. In this example, while $\eta_{LQ}(s.r.) < 1$ and $\eta_{LQ}(l.r.) > \eta_{LQ}(s.r.)$, the comparable inequalities involving E would be reversed, thus resolving the contradiction. We examine both approaches in discussing our output elasticity computations.

Concerning to the bottom panel of Table 3, we see that the short-run output elasticities for all three of the durable sector's labor inputs are less than unity, and less than their corresponding long-run output elasticity estimates: $\eta_{MQ}(s.r.) = 0.1566 < \eta_{MQ}(l.r.) = 1.2890$; $\eta_{FQ}(s.r.) = 0.5395 < \eta_{FQ}(l.r.) = 1.7010$; and $\eta_{OQ}(s.r.) = -0.0297 < \eta_{OQ}(l.r.) = 1.4282$. These results suggest increasing returns to M, F and O, and the increasing returns are largest in O, followed by M and F. Labor hoarding can be inferred from these findings.

However, we need not to go outside of our model to explain this same structure of output elasticities. The pattern of substitution elasticity in Table 2 supports it. Both K and E are long-run substitutes ($\sigma_{KE}(l.r.) = 0.8929$), a finding which suggests that the (unknown) elasticity of demand for energy with respect to output is larger in the short-run than it is in the long-run. Thus, given K's quasi-fixed nature, the short-run response to a given increase in Q is to expand energy's consumption proportionately more than Q, and also to increase the employment of M, F and O, but in much smaller proportions than Q because all three labor inputs and K are long-run complements ($\sigma_{MK} = -0.1361$, $\sigma_{FK} = -0.1403$ and $\sigma_{OK} = -0.1795$). This increases labors' productivity in the short-run. But in the long-run, as K is substituted for E, the employment of M, F and O is further increased because of the decline in their productivity caused by the substituting K for E.

From the forgoing, it is quite clear that Korea's durable sector response to an upswing (downswing) in the business cycle is to initially increase (decrease) labor input demands but by proportionally less than output increased (decreased). Then, in the long-run, the labor input demands are increased (decreased) beyond their initial adjustment levels such that in the steady-state, they are proportionately larger than Q (with long-run output elasticities exceeding unity). Moreover, from Table 3, we see that both the short-run and long-run demand for male "white collar" and production workers is far more stable with respect to variations in output than is the demand for female production workers. Turning to the non-durable sector's output elasticities in Table 3, we see an entirely different structure of labor inputs-output elasticities than the characteristics of the durable sector. In this sector short-run "overshooting" occurs. That is, the initial response to a given increase (decrease) in output is to increase (decrease) labor input demands by proportionately more. Then, over time as K increases the initial increases (decreases) in labor inputs are pared back.

To interpret overshooting, we begin by noting that M is inelastic with respect to output in the short-run (0.8425, evidence of increasing returns), while the short-run output elasticities for F and O are greater than unity (1.8382 and 1.5572, respectively). In the long-run, the respective output elasticity for M, F and O are 0.3803, 0.2756 and 0.6446, with each estimate being smaller than its short-run output elasticities and less than unity. Short-run overshooting suggests that all three labor inputs are long-run substitutes for capital, which is the case as seen in Table 2: $\sigma_{MK} = 0.0007$; $\sigma_{FK} = 0.0024$ and $\sigma_{OK} = 0.0014$ for non-durable. We do not directly estimate energy's short-run and long-run elasticities with respect to output, but since energy and capital are long-run substitutes (σ_{KE} =0 .0076) it follows that energy's short-run output elasticity is larger than its long-run output elasticity implying short-run overshooting for this input as well. Finally, capital's long-run output elasticity is 1.1933 (akin to the durable sector's elasticity), evidence of some decreasing returns to scale in that variable.

These results imply that in response to an exogenous increase (decrease) in the demand for output, the short-run Korea's non-durable sector's demand for F and O increases (decreases) by a larger proportion than Q, and so too

[5] The survey of empirical literature by Hamermesh and Grant (1979) supports this thesis.

its demand for E. This is due to the substitutability of the female and office worker inputs with K. On the other hand, the short-run demand for the male workers is not as responsive to Q's increase (decrease) because male is K's weakest substitute, which causes some short-run increasing returns to M. As K adjusts to its steady-state level, the employment of M, F, O and E are gradually reduced (increased) indicating substantial long-run increasing returns to scale in M, F, and O.

4. *Conclusions*

We began this paper by postulating that Korea's manufacturing firms behave as dynamic cost minimizers and then we proceeded to derive labor demand based on this assumption. In most instances, this assumption could not be rejected. Further, we established that the capital stock adjustment costs do increase in the margin and therefore, the capital stock adjustments are distributed over time.

We now turn to our more salient substantive findings. First, as Kim (1984), and Kwon and Williams (1982) found, our labor inputs-capital elasticities of substitution are significantly non-zero. However, while all three types of labor input are capital-complements in durable manufacturing, these three types are capital-substitutes in non-durable manufacturing. Moreover, the output-constant, labor inputs-capital substitution elasticities are all very small in absolute value. These findings do not contradict Kim's (1984) conclusion that the Korea's subsidization of capital formation has resulted in the importation of heavily biased labor-saving capital, yielding labor-capital combinations that are socially inefficient (i.e., which are inconsistent with Korea's domestic factor endowments, which favor labor insensitivities).

Nevertheless, the magnitudes of our labor-capital elasticities of substitution--as opposed to those reported by Kim (1984) or Kwon and Williams (1982)--hold relatively little promise that significant output-constant employment opportunities can be existed via policies that manipulate input prices. Of course, output is not constant in the real world. Hence, we suggest a policy evaluation focus that embraces more than substitution elasticity when considering the labor demand augmenting effects of eliminating capital formation subsidies or decrementing effects of minimum wage entitlements and collective bargaining rights. To come to grips with the labor input demand effects of these input price policies, evaluation should center on an expression like:

(1) $$\eta_{ii}|_{W_j,U} = (\eta_{ii}|_{Q,W_j,U}) + (\eta_{iQ}|_{W_j,U})\,(\eta_{QP_Q})\,(\eta_{PQj}|_{W_j,U}).$$ [6]

Equation (1) permits calculation of the gross elasticity of demand for the i^{th} input with respect to its own-price. The first term to the right of the equality sign measures the output-constant own-price (or inter-input substitution) elasticity ($\eta_{ii}|_{Q,W_j,U}$). To this term, we *add* (1) the elasticity of i^{th} demand with respect to output ($\eta_{iQ}|_{W_j,U}$) weighted by (2) the output elasticity with respect to output price (η_{QP_Q}), and (3) the output price-i^{th} input own-price elasticity($\eta_{PQj}|_{W_j,U}$), where (1), (2) and (3) are respectively the three terms to the right of the plus sign in the equation (1). Alternatively, the equation (1) can be expressed in terms of the gross elasticity of demand for the i^{th} input with respect to cross-prices.

The up-shot of our findings is that the weighted "output elasticity" term will most likely dominate the output-constant "own (cross)-price elasticity" term in most calculations of the impact of input price manipulations on labor input demands. Assuming that the terms (2) and (3) in the equation (1) are substantially greater than zero, this conclusion derives from our highly inelastic own-price and cross-price elasticity computations (refer to Table 2), paired with our highly elastic inputs-output relations (refer to Table 3). Our anticipation, for example, is that the adverse employment effects of Korea's new collective bargaining regime will not be measurably transmitted through the substitution effect. Rather, they will be transmitted through increased production costs to increased product prices and ultimately to reduced output and employment demands. This causal chain, however, will take hold only when the manufacturing industry's monopoly rents (if any) or access to government subsidies (if any) are no longer available for maintenance of price competitiveness, or when profit margins from domestic manufacturing slip below those offered from manufacturing opportunities abroad.

Second, our insignificant cross-price labor input elasticities suggest that Korea's manufacturing technology leave little room for either inter-job classification or inter-gender substitutions (refer to Table 1). These results suggest

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[6] . $|_{Q,W_j,U}$ indicates elasticity given output (Q), j^{th} input price (W_j) and user cost of capital (U).

that jobs in Korea's manufacturing industry are designed strictly to match specific employee attributes (1) that are required to perform the job, or (2) that are required to conform to culturally imposed employment restrictions. The latter restrictions are analogous to "work rules" limiting access to specific jobs within the firm to, say, "women only" or only to "high school graduates." In either case, these low inter-labor substitution elasticities greatly limit the firm's ability to shift work tasks between job classifications and genders in response to relative wage changes without significantly incrementing production costs. Further, these low elasticities also suggest that the firm's ability to maintain short-run output levels by transferring job tasks may be seriously limited in cases of work stoppages by any one class of workers.

What we are describing in the preceding paragraph are two forms of job balkanization: one based on worker classification, and the other on gender. Our gender-based job balkanization conclusion is particularly consistent with our labor inputs-output and labor inputs-technology elasticity results. With respect to the former, we found that in response to a given proportionate increase (decrease) in output, both durable and non-durable goods manufacturers respond by increasing (decreasing) their demand for (production) females by proportionately more than their demand for (production and office) males in the short-run (refer to Table 3). Likewise, based on the trend elements implicit in our measure of technology, we found that typically female versus typically male jobs are far more susceptible to the eroding (and productivity enhancing) effects brought on by technological displacement.

Another striking result is our long-run output elasticities indicate decreasing returns to M, F, O and K in durable manufacturing, and increasing returns for all three labor classes (but decreasing returns to capital) in non-durable manufacturing (refer to Table 3). Thus, in the case of durable manufacturing, these results support the guarded conclusion (recalling that we do not estimate energy-output elasticities) that scale economies, in addition to competitive efficiencies, may derive from breaking-up some of Korea's larger durable manufacturing establishments and/or by generally promoting the development of small and medium-sized establishments in that sector.

Finally, our output elasticities confirm that significantly different inter-sector and inter-labor patterns of employment volatility accompany the manufacturing business cycles, the greatest short-term effects being felt by employees in the non-durable sector, particularly with respect to the demand for female workers.

Appendix

A.1: Model and Estimation Procedure

To estimate the elasticity of inputs, input demand functions are derived and estimated, and input elasticities are calculated from the demand function parameters. Our estimates of the demand function parameters are given in A.4 in Appendix. Used to derive the input demand functions the firm's objective function can be expressed as:

$$(1) \qquad C(0) = \int e^{-rt} [\mathbf{W'V} + W_K(k + \delta K)]dt, \text{ s.t. } f(\mathbf{V},K,k,Q,T) = 0,$$

where $\mathbf{W} = \{W_M, W_F, W_E, W_K\}$, $\mathbf{V} = \{M, F, E, K\}$, r is the discount rate, and δ is the depreciation rate. To identify the firm's short- and long-run input demand relations, a two-step process is used to solve (1). First, the equation (1) is minimized with respect to the variable inputs, $\mathbf{V}$, yielding the minimum short-run cost function, conditional on K(t), Q(t) and T(t). We can express this minimized function as the quadratic form:

$$(2) \qquad C = a_o + \mathbf{A'X} + \tfrac{1}{2} \mathbf{X'BX},$$

where $\mathbf{X} = \{W_F, W_E, K, k, Q, T\}$ and vector $\mathbf{A}$ and matrix $\mathbf{B}$ are coefficient arrays. In long-run equilibrium k = 0, thus $C_{kk} = 0$. Analytically, this implies $k = a_k = b_{ik} = b_{ki} = 0$, i = F, E, K, Q, T; and further, the symmetry assumption requires that $b_{ij} = b_{ji}$, i, j = F, E. We impose both sets of restrictions in this paper. The estimates reported are based on the added modification, $b_{QQ} = b_{QT} = 0$. Lastly, we expressed $\mathbf{X}$ as we did because W_F and W_E are normalized by W_M in our analysis.

Partially differentiating (2) with respect to normalized W_i, i = F and E, yields our least-cost short-run variable input demand functions:

$$(3) \qquad V_i = a_i + \Sigma b_{ij}W_j + b_{iK}K + b_{iQ}Q + b_{iT}T, \text{ where } i, j = F, E.$$

By substituting (3) into (2) we can easily derive the least-cost short-run demand function for male production labor. Denoting the minimized short-run cost function as C(r.s.), the latter can be written as:

$$(4) \qquad M = \{C(s.r.) - \Sigma W_iV_i\} = a_0 + a_KK + a_QQ + a_TT - ½\ \Sigma\Sigma b_{ij}W_iW_j + ½\ (b_{KK}K^2 + b_{kk}k^2 + b_{TT}T^2) + b_{KQ}KQ + b_{KT}KT.$$

Second, the optimization problem requires substituting (2) for the now normalized expenditure vector **W′V** in (1). Next, given the cost minimizing conditional input demand functions for the variable inputs, we can optimize over quasi-fixed capital by minimizing the present value cost of revised (1) with respect to K(t) and k(t).

Bundt, Fuss and Waverman (1979) show the first-order condition for this minimum, expressed in derivatives of (2), to be as follows:

$$(5) \quad -C_K - rC_k - U - C_{kk}\partial k/\partial t - C_{Kk}k = 0,$$

where $U = W_K(r + d)$, the user cost of quasi-fixed capital stock.

Under sufficiency conditions, (4) can be used to derive the long-run (steady state) demand function for K, indicated by K*. By definition k = 0 in steady state and the marginal capital adjustment cost (C_k) is zero. Under these conditions, (4) can be evaluated for K = K*, yielding the long-run demand function for K*.[7] Expressed in terms of parameters from (2), this function can be expressed as:

$$(6) \qquad K^* = -1/b_{KK}\ [a_K + \Sigma b_{iK}W_i + U + b_{KQ}Q + b_{KT}T],$$

where i = F and E. Conveniently, (3) can be converted to long-run variable input demand equations by substituting (5) for K in (3).

With the cost function expressed as a quadratic, Treadway (1974) has shown that the first-order condition shown in (4) also can be expressed as the following linear differential equation which describes the firm's optimum capital stock adjustment path:

$$(7) \qquad k = A[K^*(t) - K(t-1)],$$

where the flexible accelerator, A, expressed in terms of (2)'s parameters is:

$$(8) \quad A = -½\ [r - (r_2 + 4b_{KK}/b_{kk})^{½}]$$

with 1 > A > O and where A is inversely related to r. Analytically, A is the proportion of the gap closed between K*(t) and K(t-1) per unit of time.[8] Refer to the demand function parameters given in Appendix (A.4).

Using the short-run and long-run versions of (3) and the steady-state capital stock input demand (7), accelerators and elasticities can be derived, which completely summarize the dynamic behavior of input demands. Evaluated at the point of sample means, the short-run (s.r.) and long-run (l.r.) own-price and cross-price, output and technology elasticities are calculated respectively:

$$(9) \qquad \eta_{ij}(s.r.) = (W_j/L_i)b_{ij};\ \ \eta_{ij}(l.r.) = (W_j/L_i)(b_{ij} + b_{iK}b_{jK}/b_{KK});$$

$$\eta_{iK}(l.r.) = (U/L_i)(b_{iK}/b_{KK});$$

$$\eta_{Kj}(l.r.) = (X_j/K)(b_{jK}/b_{KK}),\ \ X_j = U, W_j;$$

$$(10) \qquad \eta_{iQ}(s.r.) = (Q/L_i)b_{iQ};\ \ \eta_{iQ}(l.r.) = (Q/L_j)(b_{iQ} + b_{iK}b_{KQ}/b_{KK});$$

$$\eta_{KQ}(l.r.) = (Q/K)(b_{KQ}/b_{KK});$$

$$(11) \qquad \eta_{iT}(s.r.) = (1/L_i)b_{iT};\ \ \eta_{iT}(l.r.) = (1/L_i)(b_{iT} + b_{iK}b_{KT}/b_{KK});$$

$$\eta_{KT}(l.r.) = (1/K)(b_{KT}/b_{KK})^9;$$

where i, j = F and E in equations (9), (10) and (11).

[7] By rewriting (4), Euler's equation reduces to $-C_{K*} = U$, implying that equilibrium in K is achieved where the marginal benefits from capital stock adjustments (cost reduction) equals marginal costs (the user cost of capital).

[8] After (7) is estimated, A can be evaluated at any r and (6) can be analytically derived.

[9] Applying the standard definition of elasticity to technology (T) defies interpretation. Thus, we express η_{iT} as a unit change in T, and here a "unit" is equivalent to a one-year change.

A.2: Durable and Non-durable Manufacturing by SIC Classification (Standard Industrial Code)

Code	Industry	Classification (SIC)
00	Total Manufacturing	3
01	Total Non-durable	
	Food, Beverage, Tobacco	31
	Textile, Wearing Apparel, Leather	32
	Paper, Paper Product, Printing, Publishing	34
	Chemical, Petroleum, Coal, Rubber, Plastic Product	35
02	Total Durable	
	Wood, Wood product, and Furniture	33
	Non-metallic mineral product	36
	Basic metal	37
	Fabricated metal product, machinery, equipment	38
03	Unclassified	39

3: Variable Definitions and Constructions

1. Employment Variables: The male production worker (M), female production worker (F) and office (i.e., non-production) worker (O) are annual series based on monthly data published in Report on Monthly Labor Survey, Department of Labor (relevant issues in 1972-1991). Both the M and F series were constructed by simple averaging across months. M and F are defined as "regular" employees engaged in manufacturing production, assembly, equipment repair, inspections, packing, loading and unloading, transportation, storing, and security work whether carried out by skilled, unskilled or semi-skilled workers. In contrast, the O series aggregates male and female non-production office workers defined as "regular" employees engaged as managers, supervisors, purchasing and sales personnel, engineers, professionals, and clerical and related support services.[10] The O series was constructed by dividing annual expenditures on office workers by a Divisia wage index for male and female office workers' centered at 1979 = 1.[11]

2. Capital Stock (K). Annual series on K appears in Pyo (1992). The annual series was constructed using Pyo's net capital stock series (1985 constant prices, Table a-3).[12] Private expenditures on capital stocks were so heavily subsidized during our sampling period that we chose to use net, rather than gross capital stock to more accurately measure total private capital stock outlays. Disaggregation of Pyo's series into its durable and non-durable components was achieved using two-digit share data provided by Korea Development Institute (KDI).

3. Output. Output, Q, is measured as an index of monthly value added (1975 = 100) published in Korea Statistical Yearbook, Economic Planning Board (relevant issues in1972-1991). Simple averaging is used to convert these for annual series. Our analytical Q series are centered at 1979 = 1.

Wage Variables

1. Wages. Annual indexes for W_M(annual earnings of a male production worker) and W_F (annual earnings of a female production worker) were constructed from monthly average wages for "regular" male and female production workers published in the Report on Monthly Labor Survey. Data from this source were also used to build our annual indexes for W_O (annual earnings of a non-production worker) by the method of Divisia aggregation. All of the analytical wage indexes were normalized by W_E and centered at 1979 = 1.

2. Capital Costs. The user cost of capital, $U = W_K(r + d)$, is a composite annual index. W_K is the annual wholesale price index for capital (1980 =100) from Korea Statistical Yearbook, Economic Planning Board (relevant issues in 1972-1991), r is an annual discount rate on commercial bills obtained from Economic Statistics Yearbook, The

[10] The Report on Monthly Labor Survey defines a "regular" employee as a person who worked at least 45 days during the three months preceding the survey, or as a person employed on a permanent basis (in firms employing 10 or more workers).

[11] The Divisia indexes used in this paper were computed as $W_O = (S_{Mt})(\ln W_{Mt} - \ln W_{Mt-l}) + (S_{Ft})(\ln W_{Ft} - \ln W_{Ft-1})$, where $S_{it} = (W_{it} \times i_t)/(W_{Mt} \times Males_t + W_{Ft} \times$ Females and i = Males and Females.

[12] We wish to thank Dr. Bark, Tae Ho for calling our attention to Pyo's published series. Our earlier estimations drew on Pyo's earlier, unpublished versions of his ultimate series' estimations.

Bank of Korea (relevant issues in1972-1991) and d is fixed at 10 percent per year.[13] The resulting U composite index is normalized (W_E), converted to an annual index and centered at 1979 = 1.

3. Energy Prices (W_E). The Korea Statistical Yearbook reports a monthly fuel and electricity (excluding coal) wholesale price index. Converted to annual index, this index was used to measure W_E (centered at 1979 = 1).

A.4: Aggregate, Durable, Non-durable Manufacturing Demand Functions' Parameter Estimates, 1972-1989 (t-ratio in parenthesis).

Parameter	Durable	Non-durable	Aggregate
a_M	1.421 (4.908)	1.386 (11.91)	4.838 (17.16)
b_{MQ}	.5695 (1.391)	2.556 (9.072)	5.696 (6.045)
b_{MT}	-.7012 (-4.717)	.1171 (1.723)	-.8477 (-3.689)
b_{MM}	-.1625 (-.5781)	.1755 (.4050)	-.0934 (-.1334)
b_{MF}	.1496 (.6841)	-.9298 (-2.187)	-2.769 (-3.498)
b_{MO}	.3179 (1.086)	-.0248 (-.0569)	.6004 (.9119)
b_{MK}	.2184 (7.103)	-.0610 (-3.659)	.0008 (.0256)
a_F	.7273 (3.324)	1.353 (3.845)	7.273 (12.57)
b_{FQ}	.8885 (2.580)	9.992 (14.59)	13.50 (6.442)
b_{FT}	-.5625 (-4.463)	.5192 (2.215)	-1.804 (-3.521)
b_{FF}	.0860 (.6684)	-.2267 (-.2478)	2.760 (1.481)
b_{FO}	-.0934 (-.3889)	.2628 (.4173)	-1.350 (-1.161)
b_{FK}	.1014 (4.389)	-.3694 (-8.324)	-.1486 (-2.198)
a_O	-.3336 (-1.421)	.1466 (.5389)	3.809 (7.176)
b_{OQ}	-.0914 (-.2744)	6.561 (10.71)	8.375 (4.466)
b_{OT}	-.3066 (-2.541)	.2146 (1.245)	-1.485 (-3.420)
b_{OO}	.2923 (.7762)	-.2363 (-.2562)	-.9324 (-.8980)
b_{OK}	.2371 (9.704)	-.1672 (-4.896)	.0286 (.4717)
a_K	-10.64 (-1.554)	321.1 (1.778)	-195.8 (-2.230)
b_{KK}	.6192 (1.261)	44.25 (1.816)	77.15 (2.963)
b_{kk}	301.5 (1.145)	8990 (207.9)	9952 (63.33)
b_{KQ}	-11.67 (-1.247)	-1016 (-2.768)	-3395 (-4.258)
b_{KT}	.5790 (.4842)	-218.6 (-1.554)	-134.1 (-.7874)
A	.0408	.0640	.0833
Log of LF	173.1	113.8	-40.06

Note: After (7) in the Appendix A.1 is estimated, A in the table can be evaluated at any r.

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[13] The 0.10 rate is roughly consistent with the annual capital depreciation rate series published in the Report on Mining and Manufacturing Survey (Economic Planning Board, relevant issues in 1972-1991).

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