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Interrelated Demands for Buffer Stocks and Productive Inputs: Estimates for Two-Digit Manufacturing Industries *

by

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I. Introduction

The standard approach to the analysis of the dynamic demand for factor inputs is the multivariate flexible accelerator pioneered by Lucas (1967), Treadway (1971) and Mortenson (1973). Under the assumption that firms maximize discounted cash flow in a perfect capital market with all inputs subject to adjustment costs, this literature shows that, if firms make decisions simultaneously regarding the optimal levels of all relevant state variables (for example, inventories and productive inputs), the dynamic demands for these magnitudes will be interrelated. That is, the demand for any input will depend upon the levels of all relevant inputs in production and all factor prices associated with these productive inputs. Much of the empirical work on inventories and factor inputs has ignored these insights about optimal behavior by firms.

Consider first the labor demand literature where the early work on labor demand ignored the influence of other factor inputs on labor demand.[1] More recently, work in this area has incorporated inventories which captures the impact of the business cycle upon labor inputs.[2] But these studies ignore capital stocks (due to a lack of appropriate data) and measure capital costs by a measure of the real interest rate, without any attempt to measure capital costs on an after-tax basis (again because of data limitations). The well known work of Nadiri and Rosen (1973) remedies some of these deficiencies but suffers from other limitations. Their work aggregates inventories by stage of fabrication (inventories are thus the sum of finished goods, intermediate

[1]See Nadiri and Rosen (1973) for a survey of this early work on labor demand.

[2]See Topel (1982) and Rossana (1983, 1985).

materials and goods-in-process) and they aggregate capital into a total of both plant and equipment. Theory suggests that this is inappropriate since, for example, there is no reason to regard plant and equipment to be perfect substitutes in production, displaying identical output elasticities. Moreover, there is considerable evidence in Rossana (1985) that inventories should be disaggregated by stage of fabrication in estimated labor demand schedules. What is lacking in previous research is a comprehensive framework, building in inventories and capital stocks, which correctly disaggregates inventories and capital stocks while including a more complete array of factor prices where capital costs are measured on an after-tax basis.

If the foregoing discussion is correct regarding the need to disaggregate inventories and capital in estimated labor demand schedules, then one should estimate inventory investment equations that display this same type of disaggregation. That is, separate decision rules for each inventory component should be employed where stock adjustment effects attached to inventories, capital and labor are permitted. However, early work on inventory investment ignored input decisions by firms.[3] More recently, the simultaneous nature of inventory and input decisions has been recognized with the appearance of empirical work incorporating input levels into inventory decision rules.[4] However capital stocks are ignored in almost all of this work and capital costs are typically measured on a pre-tax basis. It is also true that much of this work ignores materials and goods-in-process inventories or, in the case of Nadiri and Rosen (1973), aggregates inventories (and capital stocks)

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[3]See Rowley and Trivedi (1975) for a survey of this literature.

[4]See Topel (1982), Maccini and Rossana (1984) and Blinder (1986) for recent examples of this line of research.

inappropriately. Finally, much of this work omits unfilled orders by failing to recognize that there is a substantial amount of production to order in industry data. As a result, unfilled orders should appear in all input demand functions and a decision rule for unfilled orders should be estimated which displays the stock adjustment effects described above.

This paper provides empirical estimates of labor demand, inventory investment and unfilled orders equations which partially synthesizes these lines of research.[5] I provide estimates of employment, hours, finished goods, unfilled orders, materials and work-in-process equations for selected two-digit manufacturing industries that display the sort of stock adjustment effects described above and which disaggregate stocks in a manner which seems plausible. These dynamic demand equations also include new orders, real wages, real materials prices (often ignored in earlier work) and after-tax capital costs for plant and equipment which are taken to be the determinants of desired or equilibrium stocks. Thus this empirical framework seems more complete than any previous study in this area.

Further, there is evidence in previous work that expectation errors have some impact upon input levels chosen by firms.[6] This evidence primarily involves errors attached to output demand but it is possible to imagine that other errors are also important. For example, if interest rates are unexpectedly high, then firms may wish to alter their input levels in response. I test for expectation error effects by including errors attached to output demand and factor prices.

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[5]Data limitations prevent me from incorporating utilization rates for plant and equipment and I do not provide estimates of capital stock equations for reasons given below.

[6]These errors are found to have impact by Topel (1982) and Rossana (1985).

The empirical results presented below provide some support for most of the propositions discussed here. All of the dynamic demand schedules display stock adjustment effects. Inventories have fairly systematic effects on labor inputs and there is clear evidence that capital stocks have an impact on labor inputs. These results also highlight the need to disaggregate capital stocks and inventories in labor demand schedules. There is evidence of a relationship between inventories, unfilled orders and capital stocks, a relationship which is largely absent in previous research. There is also some evidence that factor prices play a role in stock determination. In particular, there is some evidence that after-tax capital costs have impact upon stock levels.

The results are not without their puzzling aspects. The stock adjustment effects display asymmetries which are difficult to rationalize. For example, there is strong evidence in the hours equations that employment and hours are dynamic substitutes but the employment equations do not yield similar results. Inventories and unfilled orders seem to consistently have an impact upon labor inputs but labor inputs do not seem to have as strong an impact upon inventories and unfilled orders. Own factor prices seem to have little impact upon factor inputs yet materials prices seem to have very systematic effects on labor inputs and inventories. These are issues that need to be resolved in future research.

II. Empirical System

If we ignore expectation errors for the moment, the flexible accelerator framework can be set out compactly as follows. Let

$$X_t' = [\ E_t\ H_t\ F_t\ M_t\ G_t\ U_t\ KE_t\ KP_t\ ] \tag{1}$$

where E = Production Workers, H = Average Weekly Hours, F = Finished Goods, M =

Materials, G = Goods-In-Process, U = Unfilled Orders, KE = Equipment, KP = Plant and t refers to calendar time. If [α] is a matrix of adjustment parameters and an asterisk is used to denote a desired level, then the investment demand equations can be written in discrete time as

$$X_t - X_{t-1} = \alpha(X_{t-1} - X_t^*) \tag{2}$$

This system emerges when all elements of X_t are subject to adjustment costs. For inputs in the production function, adjustment costs are explicit in the form of training and installation costs which draw resources away from the production of final output. For finished goods and unfilled orders, they are implicit as inputs used to raise or lower output buffer stocks are subject to adjustment costs. Finished goods may also be subject to holding costs such as insurance and maintenance costs.

In terms of sign restrictions which may be relevant for the parameters in [α], it is reasonable to suppose that all diagonal elements are negative. This is a minimal stability requirement for it says that, ignoring other adjustment parameters, if the firm has more of an input than it desires, it will reduce its level.

Concerning other parameters in the adjustment matrix, intuition can be used to suggest likely sign restrictions since a formal analysis is not attempted here.[7] Consider first the labor demand schedules where it is reasonable to suppose that hours and employment are imperfect substitutes in production. If so, then it should be the case that employment (hours) should

[7]Such a model involves the analysis of a control problem with seven state variables which is obviously infeasible. This is not as difficult a problem if one is content to estimate first order (Euler) equations as in Shapiro (1986) but the disadvantage of this approach is that one cannot directly estimate parameters found in earlier research.

have a negative effect upon the demand for hours (employment). The reason is that, for example, if the firm finds that it holds more workers than it wishes to hold in long-run equilibrium, then it will plan to reduce its stock of employees and it is likely to raise hours per remaining worker as its labor force falls.

Labor inputs should be inversely related to stocks of inventories. As in Rossana (1984), firms holding excess finished goods will plan to reduce production and thus labor inputs. If labor and materials are complementary inputs in production, firms will reduce labor input levels if the firm plans to hold smaller stocks of material inputs. If firms hold excess goods-in-process,they would plan to reduce these stocks thereby reducing labor inputs. Labor inputs should be positively related to unfilled orders as if firms producing to order plan to lower their order backlog, they will raise output and thus labor inputs.

The influence of capital stocks upon labor inputs should depend upon whether labor and capital inputs are substitutes or complements in production. If they are substitutes, there should be an inverse relationship between labor demanded and capital inputs. For example, it is reasonable to suppose that equipment and labor inputs are substitutes in production whereas plant and labor inputs are likely to be complements.

In the investment equations for finished goods (unfilled orders), labor inputs should be positively (negatively) related to finished goods (unfilled orders) as rising labor inputs produce more output raising (reducing) final goods stocks (unfilled orders). A similar discussion applies to the influence of capital stocks.[8] Higher levels of intermediate materials and goods-in-process held by the firm signal planned increases in output and thus finished goods. The opposite should be true for unfilled orders. It is also possible that firms produce joint outputs where one good is produced to stock and one to order. To allow for this possibility, unfilled orders will be included in the finished goods equations and finished goods will appear in the estimated unfilled orders equations.

In the remaining inventory equations (materials and goods-in-process), firms should plan to reduce (increase) inventories if finished goods (unfilled orders) are above equilibrium levels since output should fall (rise) to eliminate the disequilibrium in the output buffer stock. Productive inputs (employment, hours and capital stocks) should be positively related to these inventories as if firms plan reduced input levels, the production of semi-finished goods should fall as well. If materials and these productive inputs are complements, then materials stocks should fall as input levels decline. If firms use up intermediate materials in production, output of semi-finished goods should rise whereas if firms plan to reduce the production of semi-finished goods, firms should hold lower levels of intermediate material inputs.

As written in (2), these factor demand equations are not very useful for empirical work as equilibrium stocks are not observable. In the present context, it is possible to specify the variables which are determinants of desired stocks; these are real new orders (q), real wages (w), real materials prices (v) and capital costs attached to equipment (ce) and plant(cp). As in Rossana (1984), new orders for output will be a determinant of equilibrium

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[8]Maccini (1984) derives a restriction like this in a model with aggregated capital.

stocks if the representative firm is imperfectly competitive and sets price so as to determine the share of industry new orders accruing to itself. The remaining elements are factor input prices which obviously determine the input mix chosen by firms. In the empirical work which follows, forecasting rules will be used to approximate expectation formation since firms pursue their investment strategies under incomplete information. The estimating equations can be compactly written if we define

$$\hat{Z}_t' = [1\ \hat{q}_t\ \hat{w}_t\ \hat{v}_t\ \hat{ce}_t\ \hat{cp}_t]' \tag{3}$$

where a circumflex is used to denote the expectation of a variable. This expression may be combined with (2) to yield

$$X_t = (I + \alpha)X_{t-1} + \beta\hat{Z}_t + \eta_t \tag{4}$$

where η is a disturbance term and where I is an identity matrix of appropriate dimension. As is customary, desired stocks are taken to be a linear function of their determinants. The coefficient matrix $[\beta]$ measures the response of stock accumulation to shifts in exogenous parameters.

Concerning sign restrictions on the elements of $[\beta]$, stocks should be increasing functions of expected new orders. An increase in output demand will require increases in production thus inducing firms to raise the level of factor inputs. Inventories of finished goods should increase as firms build up inventories to service higher expected demand levels. Unfilled orders should rise as additional new orders will enter the order backlog to be serviced in the future due to substantial delivery lags.

Concerning factor input prices, factor inputs should be inversely related to own factor prices although these effects are notoriously difficult to uncover in applied work. The effects of shifts in other factor prices depends upon whether inputs are substitutes or complements in production. If labor inputs and materials are complements, there should be an inverse relationship between labor inputs and real materials prices. If equipment and labor inputs are substitutes, an increase in the user cost of equipment should increase the levels of labor inputs as firms substitute labor for equipment. Similarly, if labor inputs are complements to the stock of plant, there should be a negative relationship between labor inputs and the user cost of plant.

In the output buffer stock equations, finished goods should be inversely related to factor prices as increases in these magnitudes reduce cash flow, inducing the firm to reduce production and the stock of finished goods. This also allows the firm to conserve on its inventory holding costs. The opposite should be true for unfilled orders as a rise in factor prices should induce the firm to raise its stock of unfilled orders since there are cost savings attached to higher stocks of unfilled orders.[9]

In the materials and work-in-process equations, it is reasonable to suppose that stocks are inversely related to real wages and materials prices as if firms plan to reduce production as these input prices rise, firms will require fewer intermediate inputs and will produce fewer semi-finished goods. It seems plausible to expect similar results regarding capital cost measures.

It is also possible that expectation errors will affect stock levels. For example, if output demand is unexpectedly high, firms will find it desirable to raise production and thus stock levels. In addition, errors about factor prices can influence input choices and inventories. Everything else aside, nominal interest rates could be higher than anticipated. If so, real interest rates and thus user costs of capital are higher than expected which may induce

[9]See Holt et.al. (1960) for further details on these cost savings.

firms to reduce inventory levels. Elsewhere, these effects should depend upon whether stocks are complements or substitutes in production. Firms may be uncertain about the nominal prices of materials inputs at the time that investment decisions are made so that real materials prices may differ from expected levels. Concerning real wages, there may be uncertainty about real wages even if labor is hired under long term contract with prespecified nominal wages if the output prices of competitors (used to arrive at a price index to deflate nominal wages) are unknown to firms. I will test for these influences as well.

The final issue to be addressed concerns the method used here to approximate expectations. I use univariate time series models described in Box and Jenkins (1976) for this purpose which is an attractive way to proceed in a rational expectations context. If the residuals from these models are white noise, agents will not systematically make forecasting errors in pursuing optimal investment rules if they use these forecasting rules. All series were differenced prior to fitting these models as unit root tests described in Dickey and Fuller (1981) indicated the need to do so. An appendix to this paper contains the parameter estimates of these time series models. These parameters are not estimated simultaneously with the parameters of the investment equations so that estimates of parameters in the investment equations will be efficient conditional on these time series models.

III. Empirical Results and Estimation Methods.

A. Data. The data used in this study are publicly available from government agencies. The Bureau of Labor Statistics publishes data on production workers, average weekly hours of production workers and average hourly earnings excluding overtime. The Bureau of Economic Analysis provides data on deflated shipments and inventories by stage of fabrication. The Census Bureau provides data on nominal shipments, new and unfilled orders and materials inventories. Output price data and materials price data were obtained by appropriately using nominal and deflated data. Real wages and materials prices were obtained by deflating with the output price index. The after-tax cost of capital is that derived in Hall and Jorgenson (1967) and I used a BAA long-term bond rate obtained from Citibase in constructing capital cost measures.

The remaining data series used to construct user costs, as well as capital stock data, were obtained from the Office of Productivity in the Bureau of Labor Statistics.[10] The data are at annual frequency for all two-digit manufacturing industries and are available for a large number of asset types for investment, depreciation rates, price deflators for investment and capital stocks. Since a quarterly analysis is of interest for macroeconomic analysis, interpolation methods must be used to generate quarterly data. Investment and capital stocks were aggregated into plant and equipment groups. Using methods devised by Boot et.al. (1967) and Ginsburgh (1973), the investment data were interpolated using data on investment in equipment and structures from the NIP accounts taken from Citibase. A depreciation rate was constructed for each asset weighting by the share of each asset in the aggregate total. Depreciation is assumed to occur evenly during the year and capital stocks were constructed using the familiar accounting identity. To interpolate prices of investment goods, I used implicit price deflators for investment again from the Citibase tape. Note that, as long as interpolated data is used only as a regressor, statistical inference may be conducted in the usual way as degrees

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[10] See Gullickson and Harper (1987) for further discussion of this data.

of freedom are not affected by using interpolated data.[11] An appendix to this paper provides more details on these interpolation procedures.

All equations were estimated using ordinary least squares. Using the likelihood ratio test devised by Durbin (1970), I tested the residuals for first and fourth order serial correlation as only seasonally adjusted data was available for this study. Wherever serial persistence was detected, I quasi-differenced the equation and reestimated using nonlinear least squares. The resulting estimates are asymptotically equivalent to maximum likelihood in this context. An appendix contains more details on serial correlation test statistics and serial correlation parameter estimates. In the tables below, R^2 is the coefficient of determination and SE is the standard error of estimate. Constants are omitted from the tables for the sake of brevity.[12]

B. Labor Demand Schedules. Estimates of the labor demand decision rules are displayed in Table 1 for selected two-digit manufacturing industries.[13] These are Apparel and Related Products (SIC 23), Chemicals and Allied Products (SIC

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[11]When used as a dependent variable, degrees of freedom are affected and there is no clear way to choosing degrees of freedom in this case. The reader may wonder why I do not report capital stock demand equations. I did estimate these and found them to be extremely disappointing under any choice of degrees of freedom. Only the lagged dependent variable was found to have any systematic influence on stock levels. In the following tables, since capital stocks and after-tax user costs are measured with error, it is reasonable to suppose that standard errors for parameters associated with these variables are understated.

[12]It has become customary to include time trends in empirical work as a proxy for capital stocks or technical progress. I checked to see if adding time trends to these equations made any difference to the results. No conclusions drawn from this study are changed by including time trends in these equations.

[13]These were not chosen arbitrarily. I fit time series models to all twenty two-digit industries. Wherever all of these models fit so as to generate white noise disturbances, I estimated the demand equations. Estimates for two additional industries are contained in an appendix and are discussed below.

28), Primary Metals (SIC 33) and Fabricated Metals Products (SIC 34).

The own-adjustment parameters are roughly consistent with the view that adjustment costs attached to employment are higher than those attached to hours as own-adjustment parameters are smaller than those in the hours equations. However, adjustment is not complete within the quarter in any equation (with one exception) so that shocks will be transmitted forward in time through both hours and employment, generating serial persistence in output produced.

These results continue to display an asymmetry in the off-diagonal adjustment parameters involving hours and employment, noted previously in Rossana (1985). Employment is a dynamic substitute for hours since, in the hours equations, employment often has a negative impact upon hours per worker. However hours are irrelevant to employment determination which suggests that hours should be treated as an input that is not subject to adjustment costs. However, the own-adjustment parameters in the hours equation suggest that hours should be treated as quasi-fixed so that these results are inconsistent.

The coefficients attached to inventories largely confirm the discussion above about the relationship between labor inputs and inventories. There is fairly solid evidence of an inverse relationship between labor inputs and inventories although goods-in-process appear to have only a minor role. This is also clearly consistent with the conjecture given above that inventories should be disaggregated in the labor demand schedules. However the results regarding unfilled orders are counterintuitive since only one equation finds a positive relationship between labor inputs and unfilled orders. These results are inconsistent with results in Rossana (1985) using monthly data. This could

Table 1
Labor Demand Schedules†

	Production Workers				Average Weekly Hours			
	23	28	33	34	23	28	33	34
E	-.052 (.066)	-.178 (.059)*	-1.01 (.096)*	-.353 (.064)*	.012 (.036)	-.045 (.017)*	-.105 (.018)*	-.093 (.024)*
H	-.018 (.166)	-.212 (.247)	-.033 (.394)	.08 (.237)	-.492 (.114)*	-.531 (.089)*	-.344 (.075)*	-.404 (.09)*
F	-.046 (.046)	-.049 (.035)	.243 (.149)	-.231 (.063)*	-.055 (.028)*	-.011 (.011)	-.035 (.028)	-.0605 (.024)*
M	-.079 (.04)*	-.075 (.039)	-.049 (.111)	-.057 (.035)	-.053 (.026)*	-.056 (.014)*	-.0072 (.021)	.02 (.013)
G	-.069 (.0303)*	.061 (.044)	.129 (.216)	.075 (.063)	.0072 (.019)	.014 (.016)	.037 (.041)	.026 (.024)
U			.146 (.051)*	-.066 (.028)*			-.0201 (.0097)*	-.023 (.011)*
KE	.069 (.039)	-.029 (.033)	-1.03 (.159)*	-.411 (.116)*	.0067 (.018)	-.0087 (.0102)	-.087 (.0303)*	-.125 (.044)*
KP	-.105 (.069)	.045 (.054)	.856 (.18)*	.53 (.168)*	-.054 (.033)	.017 (.017)	.039 (.034)	.16 (.064)*
q	.132 (.046)*	.101 (.033)*	.207 (.079)*	.187 (.0504)*	.106 (.032)*	.065 (.012)*	.101 (.015)*	.08 (.019)*
w	.201 (.118)	.011 (.031)	-.335 (.182)	-.033 (.117)	.134 (.072)	-.0016 (.0097)	.039 (.035)	-.048 (.044)
v	-.219 (.071)*	-.163 (.047)*	-.462 (.18)*	-.194 (.089)*	-.091 (.039)*	-.058 (.015)*	-.039 (.034)	.019 (.034)
ce	.54E-04 (.39E-04)	.44E-04 (.17E-04)*	-.98E-04 (.87E-04)	-.14E-04 (.32E-04)	.083E-05 (.25E-04)	.16E-04 (.62E-05)*	-.15E-04 (.16E-04)	-.16E-04 (.12E-04)
cp	-.45E-04 (.31E-04)	-.36E-04 (.14E-04)*	.78E-04 (.72E-04)	.19E-04 (.28E-04)	-.41E-05 (.2E-04)	-.13E-04 (.53E-05)*	.12E-04 (.14E-04)	.16E-04 (.11E-04)
R^2	.99	.99	.99	.97	.64	.79	.86	.84
SE	.0135	.0087	.0043	.019	.0102	.0035	.0109	.0074

†All estimates are obtained using OLS with the exception of the employment equations in 23 and 28 where nonlinear least squares is used.

An asterisk (*) denotes a parameter estimate which is significant at conventional significance levels.

Note: E = Production Workers, H = Average Weekly Hours, F = Finished Goods, M = Materials, G = Goods-in-Process, U = Unfilled Orders, KE = Stock of Equipment, KP = Stock of Plant, q = New Orders, w = Real Wages, v = Real Materials Prices, ce = Capital Costs for Equipment, cp = Capital Costs for Plant.

be attributed to measurement errors.[14] However, when expectation errors are included in these equations (see the appendix) these problems disappear.

The capital stock coefficients are found to have a significant impact upon labor inputs and the results are also consistent with the notion that capital stocks should also be disaggregated in these labor demand schedules. The evidence uncovered is that equipment and labor inputs are dynamic substitutes whereas plant is a complement to labor. These are plausible results.

The remaining parameters measure the response of labor inputs to exogenous determinants of desired stocks. Labor inputs are positively related to new orders indicating that production will rise as output demand increases. These are results found in previous research. Real wages are again irrelevant to labor demand as has been often found but materials prices are almost always significant. These are very robust results because they are also found at monthly frequencies in Rossana (1985). As will be seen, materials prices have more impact upon labor inputs than they appear to have upon the stock of materials held by firms.

There is also some evidence that after-tax user costs of capital influence labor demands and this evidence is consistent with previous discussion concerning substitution and complementarity in production. Equipment costs are positively related to labor inputs, implying that if equipment rises in price, firms substitute labor as a result. If plant user costs rise, labor input falls as they would if plant and labor are complementary inputs.

C. Output Buffer Stocks. Empirical results for the finished goods and unfilled orders equations are contained in Table 2. Speeds of adjustment, as measured

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[14]The correct way to deflate nominal unfilled orders would involve using a price distribution that corresponds to the distribution of lagged order placements obtained by firms.

by estimated own-adjustment parameters, are comparable in the two sets of equations. These parameters are thought to be implausible by many researchers since, with one exception where the adjustment speed is quite high, these results imply that costs of adjustment are very severe.[15] For unfilled orders, this seems somewhat plausible since goods produced to order are heterogeneous durable goods subject to substantial delivery lags.

There is also some evidence of interaction between labor inputs and finished goods although in one case the parameter estimate is counterintuitive. There is less evidence of a relationship between labor inputs and unfilled orders for reasons that are unclear. There is only minor evidence that materials and goods-in-process have any impact upon output buffer stocks. There is an asymmetry here that is difficult to rationalize. The labor demand schedules give fairly strong evidence of interaction between labor inputs, input inventories and buffer stocks, but these equations (as well as those in Table 3) do not provide evidence that is as strong about these stock adjustment effects.

Capital stocks are found to have a significant impact upon output buffer stocks and the results show that stocks should be disaggregated in these equations. However, there is some lack of uniformity in results across industries. In the finished goods equations, the results confirm (with one exception) restrictions derived in Maccini (1984) that excess capital, fully utilized, raises finished goods stocks. In the unfilled orders equations the results are more mixed as a positive relationship between unfilled orders and the stock of plant is found in one case but equipment has the opposite influence in the same industry.

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[15]See Feldstein and Auerbach (1976) for further discussion on this point.

Table 2
Output Buffer Stocks†

	Finished Goods				Unfilled Orders	
	23	28	33	34	33	34
E	.413 (.138)*	-.283 (.084)*	.016 (.071)	-.045 (.084)	-.412 (.157)*	-.083 (.094)
H	.361 (.364)	1.98 (.457)*	.25 (.207)	.237 (.311)	.337 (.643)	.376 (.346)
F	-.836 (.147)*	-.122 (.059)*	-.364 (.111)*	-.403 (.083)*	-.883 (.243)*	-.227 (.092)*
M	.128 (.104)	-.032 (.072)	.0041 (.053)	.036 (.046)	-.151 (.181)	-.082 (.051)
G	.053 (.074)	.011 (.083)	.0703 (.111)	.223 (.083)*	.759 (.353)*	.044 (.093)
U			-.126 (.042)*	.013 (.037)	-.441 (.084)*	-.053 (.041)
KE	.259 (.089)*	-.156 (.047)*	-.0504 (.094)	.197 (.152)	-.783 (.261)*	-.179 (.169)
KP	-.265 (.137)	.421 (.083)*	.311 (.103)*	-.155 (.221)	.686 (.294)*	.22 (.246)
q	-.069 (.092)	.057 (.0601)	.066 (.046)	-.043 (.066)	.374 (.129)*	.185 (.074)*
w	1.02 (.267)*	-.251 (.047)*	-.208 (.107)	.057 (.153)	.723 (.298)*	.101 (.171)
v	-.493 (.179)*	.135 (.078)	-.169 (.093)	-.0022 (.117)	-.754 (.294)*	-.299 (.13)*
ce	-.74E-05 (.84E-04)	.61E-04 (.3E-04)*	-.87E-04 (.38E-04)*	-.3E-04 (.41E-04)	-.66E-04 (.14E-03)	-.95E-05 (.46E-04)
cp	.2E-05 (.67E-04)	-.49E-04 (.26E-04)	.81E-04 (.32E-04)*	.27E-04 (.37E-04)	.51E-04 (.12E-03)	.96E-05 (.41E-04)
R^2	.99	.99	.99	.99	.90	.99
SE	.031	.018	.026	.026	.094	.028

†The finished goods equations in 23, 28 and 33 were estimated using OLS. The remaining equations were estimated with nonlinear least squares.

An asterisk (*) denotes a parameter estimate which is significant at conventional significance levels.

Note: E = Production Workers, H = Average Weekly Hours, F = Finished Goods, M = Materials, G = Goods-in-Process, U = Unfilled Orders, KE = Stock of Equipment, KP = Stock of Plant, q = New Orders, w = Real Wages, v = Real Materials Prices, ce = Capital Costs for Equipment, cp = Capital Costs for Plant.

Unfilled orders are included in the finished goods equations to allow for the production of joint output of goods produced to stock and to order by firms. The same idea is behind the inclusion of finished goods in the unfilled orders equations. There is evidence of joint production activity as evidence is uncovered that a reduction in the stock of unfilled orders raises finished goods as firms reallocate resources from production to order goods to the production of output to stock. Thus these outputs are substitutes in the firm's output mix. In the unfilled orders equations, both equations show that a reduction of finished goods raises unfilled orders as this again reflects the substitution of production to order as firms reallocate resources from the output of goods produced to stock.

Concerning the remaining regressors, there is no evidence of a positive relationship between finished goods and new orders unlike most previous research but there is such a relationship between new and unfilled orders. Real wages are found to have some influence but the results are conflicting. However the impact of materials prices is more substantial across industries and is uniform as these prices have negative coefficients throughout. This seems counterintuitive in the unfilled order equations. This could reflect the fact that higher materials prices induce the firm to cut production and, if imperfectly competitive, raise output price which cuts its flow of new orders. However, this requires an inverse relationship between materials prices and materials stocks which is not uncovered here as will be seen below. Finally, there is some evidence that the after-tax cost of equipment and plant have a significant impact upon finished goods but the results are not uniform.

D. Input Inventories. Table 3 provides parameter estimates for the materials and goods-in-process equations. Own-adjustment parameters are negative throughout and comparable in size to those in the finished goods and unfilled orders equations. All inventory stocks seem to be sources of serial persistance if these results are taken seriously.

Concerning off-diagonal adjustment parameters, there is evidence of interaction primarily between input inventories and hours per worker. It is plausible to expect goods-in-process to fall if hours per worker decline. Finished goods are found to have only a minimal impact as only in one goods-in-process equation is there a significant negative influence of finished goods on input inventories. This seems surprising given the results in Table 1. Unfilled orders has a more significant effect across equations although in one case, the estimated parameter is negative. There is fairly strong evidence that capital stocks and input inventories are complementary productive inputs as a positive relationship is found primarily between the stock of plant and inventories.

Input inventories seem to respond to measures of expected demand even though output inventories do not seem to respond as strongly. There is a negative relationship between real wages and materials prices and input inventories which is uniform and quite robust across industries. Curiously, materials prices seem to have their weakest influence upon materials stocks. Other inputs (labor and goods-in-process) seem more sensitive to these prices for reasons which are unclear. Finally there is some evidence that input inventories respond to user costs of capital goods but only in the goods-in-process equations. The results however are not uniform across industries.

Overall, most of these equations in all three tables show that these equations fit the data reasonably well as measured by the coefficients of determination. Serial correlation was often detected and in many cases was found at order four of the autoregressive disturbance process. This clearly

Table 3
Input Inventories†

	Materials				Goods-in-Process			
	23	28	33	34	23	28	33	34
E	.197 (.117)	.069 (.064)	-.033 (.039)	-.189 (.14)	-.017 (.17)	-.017 (.094)	-.086 (.037)*	-.122 (.084)
H	.714 (.366)	.442 (.352)	.227 (.161)	1.143 (.052)*	1.27 (.532)*	.563 (.498)	.579 (.152)*	.776 (.309)*
F	-.078 (.089)	.072 (.045)	.053 (.061)	-.108 (.13)	-.146 (.129)	.086 (.058)	-.132 (.057)*	-.095 (.082)
M	-.607 (.084)*	-.138 (.055)*	-.046 (.046)	-.385 (.124)*	-.138 (.123)	.049 (.076)	.051 (.043)	.044 (.046)
G	.149 (.064)*	-.217 (.064)*	-.002 (.089)	.059 (.146)	-.498 (.092)*	-.552 (.091)*	-.15 (.083)	-.162 (.083)*
U			.045 (.021)*	.217 (.077)*			-.052 (.019)*	.001 (.037)
KE	.038 (.059)	.011 (.035)	-.109 (.066)	.557 (.287)	.169 (.085)*	.0603 (.056)	-.063 (.062)	-.118 (.151)
KP	.204 (.105)	.061 (.065)	.228 (.074)*	-.456 (.374)	.131 (.153)	.258 (.092)*	.366 (.069)*	.275 (.22)
q	.111 (.102)	.191 (.046)*	-.031 (.032)	.119 (.103)	.351 (.149)*	.156 (.066)*	.027 (.03)	.0603 (.066)
w	.035 (.232)	-.049 (.036)	-.30 (.074)*	-.309 (.249)	.337 (.337)	-.153 (.054)*	-.142 (.0704)*	-.0054 (.152)
v	-.377 (.123)*	.104 (.059)	-.05 (.074)	.0109 (.192)	-.45 (.18)*	.033 (.085)	-.193 (.069)*	-.133 (.116)
ce	.77E-04 (.8E-04)	.22E-04 (.23E-04)	.11E-04 (.36E-04)	.26E-04 (.59E-04)	.3E-03 (.12E-03)*	-.79E-04 (.34E-04)*	-.25E-04 (.33E-04)	-.23E-05 (.41E-04)
cp	-.51E-04 (.65E-04)	-.19E-04 (.2E-04)	-.12E-04 (.29E-04)	-.19E-04 (.54E-04)	-.25E-03 (.94E-04)*	.75E-04 (.29E-04)*	.27E-04 (.28E-04)	.3E-05 (.36E-04)
R^2	.99	.99	.99	.99	.98	.99	.99	.99
SE	.033	.014	.024	.036	.047	.019	.022	.025

†Nonlinear least squares is used in the materials equations for 28 and 34 with OLS used elsewhere.

An asterisk (*) denotes a parameter estimate which is significant at conventional significance levels.

Note: E - Production Workers, H = Average Weekly Hours, F = Finished Goods, M = Materials, G = Goods-in-Process, U = Unfilled Orders, KE = Stock of Equipment, KP = Stock of Plant, q = New Orders, w = Real Wages, v = Real Materials Prices, ce = Capital Costs for Equipment, cp = Capital Costs for Plant.

indicates the need to check for inappropriate seasonal adjustment when seasonally adjusted data are used.

E. Other Empirical Results. An appendix to this paper provides evidence on some additional specifications as well as providing parameter estimates for two additional two-digit industries. Here I indicate briefly the results from these additional estimated equations.

Without expectation errors, Printing and Publishing (SIC 27) and Stone, Clay and Glass (SIC 32) industries provide more evidence that hours has an impact upon employment but the evidence is that they are complements not substitutes in production. Inventory effects are comparable to previous results but there is evidence that capital stocks have effects opposite to those described above. Real wages are found to raise labor input in two cases. Capital stocks continue to show effects on inventories as materials and goods-in-process are found to be sensitive to capital stocks. There is also evidence that materials and unfilled orders are sensitive to capital costs. Otherwise, results are comparable to those described above.

Expectation errors for new orders are found to be extremely important in all labor demand schedules. If output demand is unexpectedly high, labor inputs (and thus output) rise which is plausible and confirms previous research results on this point. There are some additional improvements elsewhere in these equations as there is no longer any evidence of an inverse relationship between labor inputs and unfilled orders; results are reversed as order backlogs have a systematically positive influence on labor inputs. There is also some stronger evidence that user costs of capital have an influence on labor inputs.

The only expectation errors which make an important difference elsewhere are in the unfilled orders equations where unexpected increases in new orders raise unfilled orders which is intuitive. Unlike much of the inventory investment literature, these errors have almost no influence on stocks of finished goods. Errors attached to factor prices also have minimal influence in these decision rules.

IV. Summary

This paper has provided estimates of dynamic demand schedules for labor, input inventories and buffer stocks of finished goods and unfilled orders. The empirical framework used here improves upon previous research in a number of ways. My approach disaggregates inventories by stage of fabrication and disaggregates capital into plant and equipment groups. I also can account for firms which produce to stock and to order by incorporating both finished goods and unfilled orders into the analysis. I also test for the effects of a more complete array of real factor input prices since I use measures of expected real wages, real materials prices and user costs for equipment and capital.

The empirical evidence presented here provides some support for all hypotheses described here. All of the estimated equations display stock adjustment effects indicating that decisions on productive inputs and inventories are made simultaneously. The results show that inventories should be disaggregated by stage of fabrication (finished goods, materials and goods-in-process) and that capital should be disaggregated into plant and equipment groups. There is some evidence that factor prices, particularly real materials prices, have an impact upon input choices by firms. There is also some evidence that after-tax capital cost measures influence input demands. However, the results have their puzzling aspects which need attention in future work in this area and a few merit mention at this point.

There are asymmetries in the estimated adjustment matrix which are difficult to rationalize. There is fairly strong evidence that inventories influence the labor input decision, but there is much less evidence that labor inputs affect inventory investment. A similar result concerns the relationship between employment and hours per worker. Own factor price effects are largely absent but raw materials prices and, to a lesser extent, real wages are found to influence labor inputs and inventories respectively. New orders are systematically related to labor inputs but not to input inventories.

Finally, one glaring omission from the empirical literature on investment (including the present study) is the lack of support for the neoclassical model of investment in capital goods.[16] There is very little work which provides any support for the neoclassical approach since, as an example, Nadiri and Rosen (1973) provide the most comprehensive test of this model and find virtually no evidence that factor prices have any influence on capital stocks. Investment theory is a basic component of macroeconomics and it would be comforting to know that there is some empirical support for the accepted approach to the theory of capital investment.

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[16]Note that empirical work with investment and Tobin's q does not fill this gap since marginal q is a function of real wages, capital costs and other variables so that this literature does not provide a direct test of this model.

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Appendix A
Univariate Time Series Models

The factor demand schedules are presumably driven by expectations of various magnitudes since firms operate under incomplete information. In this paper, univariate time series models, described in Box and Jenkins (1976), are used as a forecasting device to approximate expectations. Variables which must be forecasted are new orders (q), real wages (w), real materials prices (v), the inflation rate of output prices (π), real purchase prices of equipment (p_e) and real purchase prices of plant (p_k). Except for the inflation rate, all variables are measured in natural logarithms.

In the tables below, the results of fitting these models are displayed for the six industries used in this study. The price level and all other series were differenced as unit root tests described by Dickey and Fuller (1981) indicated the presence of unit roots and thus nonstationarity in all series. In the tables, $\theta(L)$ is a polynomial in the lag operator ($LX_t = LX_{t-1}$), ξ is a white noise disturbance, μ is a constant term, SE is the standard error of estimate and Q statistics are presented as Q(lag). Standard errors are given within parentheses beneath each estimated coefficient. The simplest models were chosen which produced white noise disturbances as measured by appropriate test statistics.

Table A.1 - New Orders

$$(1-\theta(L))(1-L)q_t = (1-\theta(L))\mu + \xi_t$$

	INDUSTRY					
	23	27	28	32	33	34
μ	.00541 (.0019)	.0068 (.066)	.0104 (.0031)			.0079 (.0062)
θ_1	-.0282 (.096)		.509 (.094)		.115 (.0904)	.188 (.095)
θ_2	-.196 (.096)		-.248 (.105)		-.187 (.091)	.072 (.095)
θ_3	-.131 (.098)		.16 (.105)		.084 (.091)	
θ_4	-.214 (.098)		-.189 (.094)		-.321 (.091)	
θ_5	.106 (.098)					
θ_6	.0418 (.098)					
θ_7	-.0484 (.096)					
θ_8	-.235 (.096)					
Q(6)	--	1.31	1.57	4.42	0.43	1.68
Q(12)	3.85	6.51	8.67	12.71	4.49	8.43
Q(18)	8.71	11.34	13.07	16.32	8.92	11.72
Q(24)	16.67	18.01	17.91	19.74	15.23	17.03
SE	.0346	.0049	.025	--	.095	.049

Table A.2 - Real Wages

$$(1-\theta(L))(1-L)w_t = (1-\theta(L))\mu + \xi_t$$

INDUSTRY

	23	27	28	32	33	34
μ	.0048 (.00071)		.0058 (.003)			
θ_1	-.17 (.095)		.70 (.096)	-.0203 (.091)	.518 (.092)	.398 (.095)
θ_2	-.137 (.093)		-.032 (.114)	.082 (.091)	-.254 (.093)	.082 (.095)
θ_3	-.32 (.093)		-.17 (.112)	.018 (.091)		
θ_4	.202 (.093)		.342 (.117)	.315 (.092)		
θ_5	-.262 (.095)		-.273 (.098)			
θ_6	-.226 (.10)					
Q(6)	--	3.47	--	1.66	4.57	2.15
Q(12)	4.06	7.65	5.72	6.36	7.12	4.50
Q(18)	5.10	10.82	10.87	11.08	12.13	12.60
Q(24)	14.94	18.63	14.32	13.60	17.49	16.95
SE	.014		.014	.012	.019	.014

Table A.3 - Real Materials Prices

$$(1-\theta(L))(1-L)v_t = (1-\theta(L))\mu + \xi_t$$

INDUSTRY

	23	27	28	32	33	34
μ		-.0039 (.0019)				
θ_1	.212 (.092)		.086 (.093)	.202 (.10)	.255 (.092)	
θ_2	-.049 (.091)		.228 (.093)	.105 (.10)		
θ_3	-.239 (.088)			-.061 (.10)		
θ_4	.291 (.091)			.415 (.10)		
θ_5	-.325 (.094)			-.18 (.10)		
θ_6				-.037 (.102)		
θ_7				.091 (.102)		
θ_8				.133 (.102)		
Q(6)	0.97	3.60	2.73	--	5.17	3.43
Q(12)	5.99	10.93	12.92	5.99	7.90	6.36
Q(18)	7.78	14.62	21.74	6.97	17.55	13.04
Q(24)	8.89	14.89	25.37	11.06	20.92	17.80
SE	.015	.0207	.014	.011	.021	

Table A.4 - Inflation

$$(1-\theta(L))\pi_t = (1-\theta(L))\mu + \xi_t$$

INDUSTRY

	23	27	28	32	33	34
μ	2.704 (.819)	4.907 (.952)	3.029 (1.95)	5.515 (1.66)	3.778 (1.63)	1.427 (1.37)
θ_1	.0777 (.089)	.2077 (.094)	.9103 (.095)	.2419 (.092)	.852 (.093)	.614 (.075)
θ_2	.0131 (.089)	.0721 (.096)	-.0511 (.129)	.1037 (.094)	-.445 (.116)	
θ_3	-.127 (.09)	.0048 (.096)	-.2335 (.13)	.1179 (.095)	.228 (.094)	
θ_4	.3717 (.091)	.1897 (.094)	.1473 (.097)	.2938 (.093)		
Q(6)	2.07	0.55	1.84	1.33	.043	1.88
Q(12)	5.95	8.97	3.51	4.48	4.99	7.24
Q(18)	10.28	13.97	5.04	10.43	12.51	16.40
Q(24)	12.89	20.23	11.25	16.19	17.63	21.85
SE	5.93	5.47	5.07	4.88	6.53	5.78

Table A.5 - Real Equipment Prices

$$(1-\theta(L))(1-L)p_{et} = \xi_t$$

INDUSTRY

	23	27	28	32	33	34
θ_1	.271 (.096)	.275 (.096)	.464 (.096)	.094 (.094)	.622 (.0902)	.346 (.09)
θ_2	(.074) (.095)	-.032 (.099)	.168 (.108)	.078 (.095)	-.337 (.0904)	
θ_3	-.158 (.095)	-.069 (.10)	-.243 (.097)	.12 (.096)		
θ_4	.307 (.098)	.211 (.097)		.259 (.097)		
θ_5	-.18 (.098)					
Q(6)	0.37	2.62	1.71	2.95	3.30	1.09
Q(12)	4.24	9.12	4.60	6.90	5.86	4.00
Q(18)	8.41	15.39	7.45	11.87	11.17	11.08
Q(24)	13.67	20.94	13.53	17.22	16.24	21.92
SE	.018	.015	.014	.013	.017	.014

Table A.6 - Real Plant Prices

$$(1-\theta(L))(1-L)p_{kt} = (1-\theta(L))\mu + \xi_t$$

INDUSTRY

	23	27	28	32	33	34
μ	.0057 (.0015)		.665 (.071)			.0036 (.0027)
θ_1				.018 (.095)	.503 (.094)	.25 (.095)
θ_2				.078 (.093)	-.212 (.094)	.068 (.098)
θ_3				.207 (.093)		.203 (.098)
θ_4				.209 (.095)		
θ_5						
Q(6)	5.45	1.76	4.91	1.06	1.21	3.36
Q(12)	8.53	8.56	6.57	4.24	3.63	4.64
Q(18)	11.02	20.50	9.28	6.65	8.52	7.82
Q(24)	13.19	25.91	14.43	10.90	12.64	15.76
SE	.017		.013	.012	.017	.014

Appendix B

Serial Correlation Results

Since these factor demand equations contain lagged dependent variables, it is important to test for serial correlation in the disturbances as ordinary least squares estimates are inconsistent if there is serial persistence in the disturbances. Durbin (1970) devised a likelihood ratio test which is applied here to test for first and fourth order serial correlation in the autoregressive process

$$\eta_t = \rho_1\eta_{t-1} + \rho_2\eta_{t-4} + \zeta_t$$

where η_t is the disturbance in each estimated equation and ζ_t is a mean zero disturbance with scalar covariance matrix. Since the data are seasonally adjusted, it is useful to test for fourth order serial correlation as inappropriate seasonal adjustment can induce serial persistence at the fourth order of the autoregressive disturbance process. Test statistics for each factor demand schedule are given in the following tables. An asterisk denotes statistical significance.

Table B.1

Serial Correlation Test Statistics - No Expectation Errors

Employment Equations

	INDUSTRY					
	23	27	28	32	33	34
ρ_1	2.527*	-0.447	1.775*	-3.278*	1.488	1.520
ρ_4	-0.908	0.183	0.765	0.468	-0.388	-0.668

Hours Equations

	INDUSTRY					
	23	27	28	32	33	34
ρ_1	-0.730	0.094	1.178	-0.061	0.913	-1.204
ρ_4	-0.879	-2.034*	-0.218	-0.075	1.030	0.118

Finished Goods Equations

	INDUSTRY					
	23	27	28	32	33	34
ρ_1	2.075*	-0.876	0.248	-0.854	2.511*	-0.860
ρ_4	-1.521	-0.309	-1.782*	-0.385	-2.539*	0.303

Materials Equations

	INDUSTRY					
	23	27	28	32	33	34
ρ_1	-0.413	-0.322	-0.327	-1.169	0.740	1.961*
ρ_4	-2.501*	-0.760	-2.521*	-2.006*	-1.353	-2.921*

Work-In-Process Equations

	INDUSTRY 23	27	28	32	33	34
ρ_1	-0.642	-0.456	-0.368	-0.054	1.060	-1.370
ρ_4	-1.280	-1.082	-0.250	-1.495	-0.460	0.051

Unfilled Orders Equations

	INDUSTRY 27	32	33	34
ρ_1	1.647*	-2.384*	1.141	0.418
ρ_4	-1.419	-0.372	0.047	-0.557

Wherever serial correlation was detected, the equation was appropriately quasi-differenced and all parameters were estimated simultaneously by nonlinear least squares which is asymptotically equivalent to maximum likelihood. Asymptotically efficient estimates of the serial correlation parameters are presented below with standard errors given within parentheses beneath each estimated coefficient.

Table B.2

Serial Correlation Parameter Estimates

	Employment Equations INDUSTRY			Hours Equation INDUSTRY
	23	28	32	27
ρ_1	.438 (.152)	.301 (.128)	.373 (.105)	
ρ_4				-.263 (.111)

	Finished Goods Equations INDUSTRY			Unfilled Orders Equations INDUSTRY	
	23	28	33	27	32
ρ_1	.512 (.14)		-.188 (.148)	.204 (.117)	-.251 (.129)
ρ_4	-.258 (.096)	-.226 (.11)	-.233 (.09)	-.162 (.113)	

	Materials Equations INDUSTRY			
	23	28	32	34
ρ_1				.246 (.159)
ρ_4	-.263 (.104)	-.273 (.112)	-.217 (.118)	-.275 (.096)

Appendix C

Capital Stock Data

The Office of Productivity in the Bureau of Labor Statistics provides capital stock and investment data in constant dollars for a variety of asset types and industries. These series as well as related ones are available at annual frequency so that interpolation methods must be used to allow empirical analysis at quarterly frequency. The methods used here follow methods developed by Boot et.al. (1967) and Ginsburgh (1973).

The first step in the analysis generates quarterly interpolated investment data, $\hat{y}_j$, which solve the problem

$$\text{minimize} \quad \sum_{j=2}^{4N} (\hat{y}_j - y_{j-1})^2$$

subject to

$$\sum_{j=4i-3}^{4i} y_j = y_i^* \qquad (i = 1,2,----,N)$$

As asterisk refers to an observed annual observation. Here, i refers to annual observations and j refers to quarterly observations. The method thus creates a quarterly series which minimizes the squared differences over time in the constructed series subject to adding up constraints. As pointed out by Ginsburgh (1973), this method generates autocorrelated errors, adds no degrees of freedom and fails to take account of relevant quarterly information.

To rectify these problems, compute the regression

$$y_i^* = \hat{a}_o + \hat{a}_1 x_i^*$$

where x_i^* is a related annual time series. The final interpolated series is constructed using

$$y_j = \hat{y}_j + \hat{a}_1(x_j - \hat{x}_j)$$

If the units of measurement on y_i^* and x_j are the same, the method constructs a quarterly series which minimizes

$$\sum_{j=2}^{4N} (\Delta y_j - \Delta x_j)^2$$

under the adding up constraints given above. Note that Δ is the first difference operator.

This method was applied to gross investment data where disaggregated annual investment data were first aggregated to plant and equipment groupings for each industry. Using data from the GNP accounts on constant dollar investment in structures and durable equipment provided in Citibase, I generated quarterly investment data. Using capital stock data for 1948 as an initial value, quarterly capital stocks were obtained assuming that depreciation occurred at the same rate each quarter. Investment price deflators, used in constructing measures of capital costs, were constructed using the same methods, using implicit price deflators for producer's durable equipment and nonresidential fixed investment in structures from the GNP accounts, again provided in Citibase. Tax parameters, available on an annual basis, were taken to be the same during each quarter of the year.

Appendix D

Additional Empirical Results

This appendix contains parameter estimates for two additional industries which are not reported in the body of the paper. These industries are SIC 27 (Printing and Publishing) and SIC 32 (Stone, Clay and Glass Products). I also estimated the factor demand schedules when expectation errors are allowed in each equation. Whenever these are found to be significant, the equation is presented along with test statistics for serial correlation and estimated serial correlation parameters. An asterisk again denotes statistical significance.

Table D.1
Serial Correlation Test Statistics - No Expectation Errors

	Production Workers		Average Weekly Hours		Finished Goods	
	27	32	27	32	27	32
ρ_1	-0.447	-3.278*	0.091	-0.061	-0.876	-0.854
ρ_4	0.183	0.468	-2.034*	-0.075	-0.309	-0.385

	Materials		Goods-in-Process		Unfilled Orders	
	27	32	27	32	27	32
ρ_1	-0.322	-1.169	-0.456	-0.054	1.647*	-2.384*
ρ_4	-0.760	-2.006*	-1.082	-1.495	-1.419	-0.372

Table D.2
Labor Demand and Finished Goods Equations[†]

	Production Workers		Average Weekly Hours		Finished Goods	
	27	32	27	32	27	32
E	-.202 (.039)*	-.387 (.076)*	-.042 (.02)*	-.112 (.028)*	.025 (.169)	.266 (.118)*
H	.601 (.154)*	.623 (.302)*	-.208 (.086)*	-.398 (.107)*	.592 (.671)	.412 (.455)
F	.023 (.016)	-.227 (.052)*	.015 (.009)	-.0099 (.019)	-.332 (.072)*	-.348 (.084)*
M	-.033 (.012)*	-.0021 (.059)	-.019 (.0062)*	-.014 (.022)	.049 (.051)	.035 (.095)
G	-.0082 (.018)	-.018 (.047)	-.0045 (.0101)	-.016 (.017)	.099 (.078)	-.083 (.074)
U	.0056 (.0066)	.036 (.023)	.52E-03 (.0036)	-.015 (.0083)	-.075 (.029)*	-.037 (.035)
KE	.187 (.064)*	-.092 (.109)	.068 (.034)*	-.063 (.041)	-.092 (.281)	.146 (.173)
KP	-.14 (.049)*	-.31 (.128)*	-.0702 (.027)*	-.0038 (.049)	.247 (.213)	.339 (.211)
q	.038 (.032)	.019 (.075)	.021 (.018)	.092 (.025)*	.045 (.141)	.0018 (.108)
w	.036 (.032)	.677 (.132)*	.015 (.016)	.106 (.049)*	-.257 (.14)	-.323 (.211)
v	-.105 (.028)*	-.59 (.11)*	-.026 (.015)	-.065 (.039)	.158 (.123)	.138 (.166)
ce	.46E-04 (.31E-04)	-.46E-04 (.66E-04)	.43E-05 (.17E-04)	.34E-05 (.24E-04)	.12E-04 (.13E-03)	-.26E-04 (.10E-03)
cp	-.42E-04 (.26E-04)	.34E-04 (.57E-04)	-.65E-05 (.14E-04)	-.11E-04 (.21E-04)	.13E-04 (.11E-03)	.3E-04 (.88E-04)
R^2	.99	.99	.99	.86	.99	.97
SE	.0067	.019	.0036	.0058	.029	.025

[†]Estimates are obtained using OLS with the exception of the employment equation in 32 and the hours equation in 27 where nonlinear least squares was used. Estimated serial correlation parameters are $\hat{\rho}_1 = -.373$ (.105) in the employment equation and $\hat{\rho}_4 = -.263$ (.111) in the hours equation.

Table D.3
Input Inventories and Unfilled Orders†

	Materials		Goods-In-Process		Unfilled Orders	
	27	32	27	32	27	32
E	.012 (.22)	.118 (.096)	.268 (.226)	.199 (.16)	-.816 (.361)*	.134 (.223)
H	1.57 (.872)	-.325 (.359)	1.98 (.897)*	-.0096 (.619)	.399 (1.33)	1.22 (.876)
F	-.0904 (.093)	-.043 (.062)	.073 (.096)	.141 (.114)	-.0093 (.149)	-.183 (.141)
M	-.192 (.066)*	-.179 (.073)*	-.046 (.068)	.112 (.129)	.045 (.106)	-.039 (.162)
G	-.08 (.102)	-.105 (.06)	-.573 (.105)*	-.564 (.101)*	-.265 (.144)	.104 (.129)
U	.083 (.037)*	.026 (.027)	.032 (.038)	-.0045 (.048)	-.147 (.063)*	-.128 (.063)*
KE	-.256 (.364)	.411 (.134)*	-.202 (.375)	.08 (.236)	.737 (.552)	.202 (.298)
KP	.545 (.277)*	-.185 (.157)	.572 (.285)*	.361 (.288)	-.631 (.422)	-.788 (.35)*
q	.157 (.183)	.156 (.091)	-.018 (.188)	.0078 (.147)	.31 (.272)	-.025 (.225)
w	-.068 (.181)	-.116 (.156)	-.201 (.187)	-.14 (.287)	.256 (.297)	.81 (.356)*
v	.27 (.16)	.173 (.132)	-.095 (.164)	-.92E-03 (.226)	-.639 (.243)*	.083 (.30)
ce	-.23E-03 (.17E-03)	.17E-03 (.8E-04)*	-.2E-05 (.18E-03)	.27E-04 (.14E-03)	.57E-03 (.25E-03)*	.97E-04 (.18E-03)
cp	.19E-03 (.14E-03)	-.14E-03 (.69E-04)*	.64E-05 (.18E-03)	-.59E-05 (.12E-03)	-.43E-03 (.21E-03)*	-.12E-03 (.16E-03)
R^2	.99	.99	.98	.97	.99	.99
SE	.038	.019	.039	.034	.049	.048

† Ordinary least squares results are presented in the materials equation for industry 27 and the goods-in-process equations. Serial correlation parameter estimates are $\hat{\rho}_4$ = -.217 (.118) in the materials equation for industry 27, $\hat{\rho}_1$ = .293 (.123) in the unfilled orders equation for industry 27 and $\hat{\rho}_1$ = -.251 (.129) in the unfilled orders equations for industry 32.

In the tables which follow, I provide serial correlation test statistics and empirical estimates of the factor demand schedules when expectation errors are incorporated. Wnerever there was no evidence that these errors matter, I do not report any results.

Table D.4
Serial Correlation Test Statistics

Employment

	23	28	32	33	34
ρ_1	1.209	1.801*	-2.085*	-0.169	0.886
ρ_4	-0.276	0.532	-1.047	0.077	0.110

Average Weekly Hours

	27	28	32	33	34
ρ_1	0.257	0.948	1.014	1.537	-1.207
ρ_4	-1.165	-0.736	-1.690*	-0.084	-0.521

	Finished Goods 28	Finished Goods 33	Materials 28
ρ_1	0.322	2.054*	-0.733
ρ_4	-2.104*	-1.919*	-3.197

	Goods-in-Process 27	Goods-in-Process 34	Unfilled Orders 27	Unfilled Orders 32	Unfilled Orders 33	Unfilled Orders 34
ρ_1	-0.606	-1.402	0.471	0.552	0.053	2.082*
ρ_4	-0.987	0.148	-1.600*	-0.011	-1.172	-1.79*

Table D.5
Employment Equations - Expectation Errors†

	Industry 23	28	32	33	34
E	-.073 (.048)	-.189 (.053)*	-.324 (.061)*	-.793 (.086)*	-.302 (.053)*
H	.115 (.147)	-.148 (.221)	.152 (.234)	-.335 (.388)	-.229 (.206)
F	-.051 (.036)	-.052 (.033)	-.164 (.039)*	.412 (.129)*	-.147 (.056)*
M	-.089 (.034)*	-.092 (.036)*	.016 (.045)	-.0076 (.097)	.017 (.028)
G	-.062 (.025)*	.067 (.04)	-.043 (.038)	-.19 (.186)	-.052 (.053)
U			.037 (.019)*	.176 (.044)*	-.035 (.023)
KE	.036 (.024)	-.068 (.031)*	-.111 (.082)	-.601 (.153)*	-.40 (.097)*
KP	-.037 (.042)	.076 (.048)	-.105 (.098)	.472 (.16)*	.55 (.141)*
q	.218 (.043)*	.154 (.0305)*	.154 (.061)*	.232 (.069)*	.283 (.046)*
w	.072 (.097)	-.053 (.03)	.307 (.109)*	-.515 (.187)*	-.262 (.107)*
v	-.163 (.053)*	-.123 (.046)*	-.357 (.105)*	-.265 (.156)	-.141 (.079)
ce	.11E-03 (.34E-04)*	.48E-04 (.18E-04)*	-.21E-04 (.52E-04)	-.16E-03 (.89E-04)	-.47E-04 (.29E-04)
cp	-.92E-04 (.27E-04)*	-.39E-04 (.15E-04)*	.3E-04 (.46E-04)	.11E-03 (.73E-04)	.48E-04 (.26E-04)
Er.q	-.181 (.044)*	-.195 (.034)*	-.33 (.045)*	-.274 (.066)*	-.286 (.038)*
Er.w	.157 (.157)	-.0067 (.12)	.024 (.328)	-2.084 (.537)*	.352 (.279)
Er.v	-.168 (.114)	-.034 (.0601)	.109 (.196)	-.042 (.303)	.128 (.104)
Er.ce	.28E-05 (.24E-04)	-.15E-04 (.15E-04)	-.32E-04 (.33E-04)	.16E-03 (.72E-04)*	.31E-04 (.18E-04)
Er.cp	.68E-07 (.18E-04)	.14E-04 (.15E-04)	.2E-04 (.26E-04)	-.88E-04 (.58E-04)	-.32E-04 (.16E-04)
R^2	.98	.99	.99	.93	.98
SE	.013	.0075	.014	.047	.015

† Estimated serial correlation parameters are $\hat{\rho}_1$ = .304 (.122) in SIC 28 and $\hat{\rho}_1$ = .435 (.112) in SIC 32.

Table D.6
Average Weekly Hours Equations - Expectation Errors†

	Industry				
	27	28	32	33	34
E	-.032 (.021)	-.039 (.016)*	-.117 (.023)*	-.073 (.017)*	-.079 (.022)*
H	-.262 (.086)*	-.544 (.084)*	-.611 (.086)*	-.416 (.075)*	-.48 (.084)*
F	.0093 (.0087)	-.011 (.0104)	-.0014 (.014)	-.0064 (.025)	-.032 (.023)
M	-.014 (.0064)*	-.065 (.013)*	-.034 (.018)	.0104 (.019)	.0101 (.012)
G	-.015 (.0097)	.019 (.015)	-.022 (.015)	-.037 (.036)	-.0071 (.022)
U	-.84E-03 (.0035)		-.0066 (.0073)	-.0054 (.0085)	-.015 (.0094)
KE	.044 (.037)	-.014 (.0093)	-.061 (.032)	.1E-03 (.029)	-.101 (.039)*
KP	-.06 (.028)*	.023 (.015)	.078 (.038)*	-.038 (.031)	.12 (.058)*
q	.0402 (.018)*	.074 (.011)*	.157 (.022)*	.12 (.013)*	.099 (.019)*
w	.015 (.018)	-.013 (.0094)	-.037 (.041)	.018 (.036)	-.062 (.044)
v	-.04 (.016)*	-.064 (.016)*	-.025 (.038)	.0052 (.03)	.0046 (.032)
ce	.81E-05 (.17E-04)	.15E-04 (.64E-05)*	.4E-05 (.21E-05)	-.78E-05 (.17E-04)	-.17E-04 (.12E-04)
cp	-.92E-05 (.14E-04)	-.12E-04 (.55E-05)	-.59E-05 (.18E-04)	.75E-05 (.14E-04)	.16E-04 (.11E-04)
Er.q	-.064 (.021)*	-.063 (.015)*	-.112 (.014)*	-.08 (.013)*	-.079 (.015)*
Er.w	.113 (.101)	.0314 (.054)	.082 (.098)	-.096 (.104)	-.148 (.114)
Er.v	.0103 (.022)	.073 (.026)*	.098 (.063)	.033 (.059)	.10 (.042)*
Er.ce	.11E-05 (.78E-05)	-.81E-05 (.68E-05)	.35E-05 (.92E-05)	.11E-04 (.14E-04)	.97E-05 (.75E-05)
Er.cp	-.25E-05 (.64E-05)	.66E-05 (.54E-05)	-.4E-05 (.75E-05)	-.1E-04 (.11E-04)	-.97E.05 (.64E-05)
R^2	.95	.84	.99	.91	.90
SE	.0035	.0032	.0044	.0089	.0062

†The estimated serial correlation parameter in SIC 32 is $\hat{\rho}_4$ = -.251 (.11).

Table D.7
Inventory Equations - Expectation Errors†

	Finished Goods 28	Finished Goods 33	Materials 28	Goods-In-Process 27	Goods-In-Process 34
E	-.27 (.077)*	-.0085 (.064)	.057 (.058)	.205 (.236)	-.099 (.085)
H	1.831 (.445)*	.109 (.212)	.22 (.333)	1.81 (.947)	.659 (.334)*
F	-.151 (.063)*	-.391 (.093)*	.094 (.046)*	.0705 (.096)	-.039 (.092)
M	.027 (.078)	.037 (.049)	-.221 (.055)*	.0097 (.071)	.018 (.046)
G	-.014 (.078)	.047 (.098)	-.206 (.06)*	-.632 (.107)*	-.222 (.086)*
U		-.117 (.034)*		.023 (.038)	.018 (.037)
KE	-.139 (.043)*	-.095 (.093)	.0068 (.032)	-.395 (.408)	-.088 (.157)
KP	.371 (.079)*	.364 (.093)*	.126 (.0602)*	.613 (.305)*	.257 (.228)
q	.045 (.057)	.114 (.046)*	.22 (.043)*	.139 (.204)	.107 (.075)
w	-.191 (.045)*	-.18 (.112)	-.084 (.033)*	-.127 (.194)	-.122 (.174)
v	.123 (.083)	-.195 (.083)*	.013 (.061)	-.244 (.172)	-.083 (.127)
ce	.55E-04 (.32E-04)	-.94E-04 (.47E-04)	.73E-05 (.24E-04)	-.23E-04 (.19E-03)	-.2E-04 (.48E-04)
cp	-.4E-04 (.27E-04)	.96E-04 (.39E-04)*	-.11E-04 (.2E-04)	.3E-04 (.15E-03)	.14E-04 (.42E-04)
Er.q	.262 (.075)*	-.023 (.034)	-.187 (.056)*	-.301 (.228)	-.177 (.062)*
Er.w	.018 (.274)	1.088 (.318)*	-.179 (.204)	.0401 (1.11)	-.287 (.452)
Er.v	.129 (.128)	-.52E-03 (.144)	.206 (.096)*	.53 (.24)*	-.05 (.168)
Er.ce	.29E-04 (.37E-04)	.23E-04 (.36E-04)	.24E-04 (.28E-04)	-.37E-04 (.26E-04)	.33E-04 (.29E-04)
Er.cp	-.31E-04 (.3E-04)	-.46E-04 (.29E-04)	-.12E-04 (.22E-04)	.26E-04 (.7E-04)	-.22E-04 (.26E-04)
R^2	.99	.99	.99	.98	.99
SE	.017	.023	.013	.038	.025

†In the finished equation for SIC 28, $\hat{\rho}_4$ = -.307 (.115), for SIC 33 $\hat{\rho}_1$ = .124 (.138), $\hat{\rho}_4$ = -.217 (.078) and the materials equation for SIC 28 has ρ_4 = -.368 (.111).

Table D.8
Unfilled Orders Equations - Expectation Errors †

	Industry 27	32	33	34
E	-.813 (.262)*	.278 (.174)	-.26 (.112)*	-.081 (.066)
H	-.666 (1.12)	-.098 (.679)	-.708 (.506)	.479 (.263)
F	-.044 (.112)	.0031 (.123)	-.477 (.169)*	-.12 (.069)
M	.161 (.0801)*	.073 (.143)	-.05 (.127)	-.138 (.037)*
G	-.29 (.127)*	.025 (.112)	.138 (.242)	-.057 (.07)
U	-.149 (.047)*	-.142 (.059)*	-.252 (.058)*	.0201 (.0304)
KE	.135 (.456)	.066 (.254)	-.12 (.20)	.099 (.124)
KP	-.471 (.351)	-.232 (.324)	.116 (.209)	-.056 (.178)
q	.79 (.246)*	.395 (.168)*	.67 (.091)*	.283 (.057)*
w	.357 (.206)	-.166 (.346)	.071 (.243)	-.086 (.14)
v	-.75 (.205)*	.768 (.31)*	-.303 (.204)	-.115 (.103)
ce	.52E-03 (.21E-03)*	.17E-03 (.16E-03)	-.44E-04 (.12E-03)	.11E-03 (.36E-04)*
cp	-.4E-03 (.17E-03)*	-.13E-03 (.14E-03)	.34E-04 (.96E-04)	-.83E-04 (.31E-04)*
Er.q	-.961 (.259)*	-.902 (.108)*	-.952 (.087)*	-.43 (.042)*
Er.w	.014 (1.19)	.023 (.824)	1.99 (.701)*	-.176 (.263)
Er.v	.626 (.266)*	.146 (.516)	.419 (.397)	-.106 (.112)
Er.ce	-.79E-04 (.93E-04)	-.22E-04 (.8E-04)	-.72E-04 (.93E-04)	-.75E-04 (.2E-04)*
Er.cp	.58E-04 (.77E-04)	.43E-05 (.66E-04)	.1E-04 (.76E-04)	.58E-04 (.18E-04)*
R^2	.99	.99	.96	.99
SE	.043	.036	.0607	.016

†In SIC 27, $\hat{\rho}_4$ = -.199 (.112) and in SIC 34, $\hat{\rho}_1$ = .258 (.119) $\hat{\rho}_4$ = -.224 (.11).