NBER WORKING PAPERS SERIES

SHORT AND LONG RUN EXTERNALITIES

Eric J. Bartelsman

Ricardo J. Caballero

Richard K. Lyons

Working Paper No. 3810

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 1991

Federal Reserve Board, Columbia University and NBER, and Columbia University and NBER, respectively. We are grateful to Glenn Hubbard, Danniel Tsiddon, Manuel Trajtenberg and seminar participants at the Pinhas Sapir Conference 1991 for their useful comments. Ricardo Caballero acknowledges the National Science Foundation for financial support under grant SES-9010443. This paper is part of NBER's research programs in Economic Fluctuations and International Studies. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

NBER Working Paper #3810
August 1991

SHORT AND LONG RUN EXTERNALITIES

ABSTRACT

In this paper we build upon previous work on external economies in manufacturing [Caballero and Lyons (1989, 1990)] by providing new evidence helpful for discriminating between different types of externalities. We investigate four-digit level input-output relationships and find that, over shorter horizons, the linkage between an industry and its customers is the most important factor in the transmission of externalities. This suggests that transactions externalities accruing primarily to the seller, and/or activity-driven demand externalities are significant for explaining the short-run behavior of measured total factor productivity. Over longer horizons, on the other hand, it is the activity level of *suppliers* that is more important. This suggests that external effects are also operating through intermediate goods linkages.

Eric J. Bartelsman
Board of Governors of the
Federal Reserve System
Washington, D.C. 20551

Ricardo J. Caballero
Economics Department
Columbia University
New York, NY 10027
and NBER

Richard K. Lyons
Graduate Business School
Columbia University
New York, NY 10027
and NBER

1 Introduction

Although inherently ill-defined, externalities have always had an important role in economic theory and policy design. The burgeoning new growth and multiple equilibria literatures have enhanced this role lately. The channels for these externalities are multiple and the frequency at which they operate also varies substantially.

In sharp contrast, work on the empirical relevance of these externalities is scarce. On one hand, there is the specialized work on R&D spillovers which emphasizes the difficulty in appropriating benefits of one's own innovative activity.[1] On the other, there is the less-focused but comprehensive evidence from Caballero and Lyons (1989,1990) of significant external economies in U.S. and European manufacturing.[2]

In this paper we build on Caballero and Lyons' (1989,1990) findings and methodology, and attempt to narrow down the type of externalities that are prevalent and the frequency at which they operate. In particular, we ask: What are the sources of these externalities? What is the transmission mechanism? Is the story changed over longer horizons or at more disaggregated levels? By using data at the four-digit level and pursuing several different exploratory directions based on input-output relationships, this paper begins answering these important questions.

We group the types of external effects provided by theory into two broad categories: external effects that are likely to be operative over shorter horizons, which we will refer to as fluctuations-oriented, and those that are more likely to be operative over longer horizons, which we will refer to as growth-oriented. Among the fluctuations-oriented effects, the most prominent are transactions and aggregate demand externalities. These externalities, also sometimes called thick-market externalities, are formalized in several different ways. Most of them derive from Diamond's (1982) search-theoretic framework where an externality results from the

[1] See e.g. Bartelsman (1990), Bernstein and Nadiri (1988), Bresnahan (1986), Griliches and Lichtenberg (1984), Jaffe (1986), and Mohnen (1989).

[2] Recent empirical work by Benhabib and Jovanovic (1991) finds no evidence of externalities that are associated with capital. Caballero and Lyons (1989, 1990), on the other hand, use a less structural approach that admits broader measures of activity.

higher probability of matching between the appropriate agents when activity levels are high.[3]

The growth-oriented externalities, those more likely to be operative over longer horizons, tend to concentrate on the propagation of knowledge.[4] This can occur directly [e.g. Romer (1986a)] or through intermediate-goods linkages, which hinge either on greater specialization in intermediates [e.g. Ethier (1982) and Romer (1986b)] or on the input-output transmission of technological progress [e.g. Rosenberg (1982)].

In this paper we use input-output information to disentangle some of these externalities. We find that both types of externalities, fluctuations and growth, are operative in postwar U.S. manufacturing data. The linkage between an industry and its customers is important for explaining changes in measured productivity over shorter horizons, suggesting fluctuations-oriented effects. Over longer horizons, on the other hand, linkages with suppliers are more important, suggesting that growth-oriented externalities operating through intermediate goods are important as well.

The remainder of the paper is organized in three sections and a two-part appendix. Section 2 presents the core model and the econometric insights that permit the externality disentanglement. In Section 3 we present the results, including some consideration of the role of excess capacity. Section 4 concludes. The data and several robustness tests are discussed in the appendix.

2 The Core Model and Some Econometric Considerations

Expressing all variables in rates of growth (log differences), one can express a

[3]For a conceptual overview of relevant issues, see Hall's (1989) treatment of temporal agglomeration externalities. See also related work by Cooper and John (1988), Durlauf (1990), Milgrom and Roberts (1989), Hammour (1990) and Murphy, Shleifer, and Vishny (1989), among others.

[4]See, for a recent example, Adams (1990) or Bartelsman (1990).

generic production function that includes externalities in the following simple form:

$$y_{it} = \gamma x_{it} + \beta x_{it}^{a} + v_{it} \tag{1}$$

where y_{it} is the growth rate in real value added in industry i; x_{it} is the growth rate in industry i's inputs [defined as $\alpha_{it} l_{it} + (1 - \alpha_{it}) k_{it}$, with α_{it} the share of labor in total costs, l_{it} the growth rate of labor input (hours), and k_{it} the growth rate of capital input]; x_{it}^{a} is some weighted average of other industries' activity, as measured by the growth rate of their inputs, and v_{it} is the growth rate of industry i's technology.

The coefficient γ captures the conventional degree of internal returns to scale, while β (possibly a vector) captures any external effects deriving from changes in aggregate activity levels. In Caballero and Lyons (1989, 1990) the index i corresponds to two-digit manufacturing industries; thus, β captures externalities operative between the two-digit and aggregate levels. The *within* or *fixed effects* estimate of β —for the case in which x_{it}^{a} is the rate of growth of manufacturing inputs— is significant in each of the countries considered, with an average magnitude of approximately 0.3 in those countries for which data availability provides the most power. A battery of robustness tests support the interpretation that the coefficient does represent an externality. Additionally, more power and insights on the macroeconomic implications of these externalities are gained by juggling different levels of aggregation simultaneously. In this paper, we lose much of the ability to find aggregate implications of the externalities by juggling different levels of aggregation simultaneously; however, much is gained by using the rich interindustry structure which is available at the four digit level to trace the effects of the externalities through the economy. The subindex i is now a four-digit index.

Since one of our objectives is to disentangle short from long run externalities, we enrich the characterization of the panel by allowing different coefficients in the within and between dimensions of the data. The within estimator, by removing the sample time-averages for each industry, puts greater emphasis on the fluctuations-oriented relationships. The between estimator, on the other hand, removes all the fluctuations and thereby emphasizes on the longer-horizon relationships.

To formalize the separation of these two estimators, we dissect the disturbance in equation (1) into three components: a constant common across all industries, an industry specific constant, and a residual,

$$v_{it} = \theta_0 + \theta_i + \theta_{it}.$$

In turn, the industry specific term has three components: one that is related to its own industry average rate of input growth, another that is related to a measure of the average rate of growth of more aggregate input measures, and a constant,

$$\theta_i = \lambda_1 \bar{x}_i + \lambda_2 \bar{x}_i^a + v_i,$$

where the bar denotes a time average. If we use a dot to denote deviations from the time averages, equation (1) can be rewritten as follows:

$$y_{it} = \theta_0 + \gamma \dot{x}_{it} + \beta \dot{x}_{it}^a + (\gamma + \lambda_1)\bar{x}_i + (\beta + \lambda_2)\bar{x}_i^a + v_i + \theta_{it}$$

or, more compactly, as

$$y_{it} = \theta_0 + \gamma \dot{x}_{it} + \beta \dot{x}_{it}^a + \bar{\gamma}\bar{x}_i + \bar{\beta}\bar{x}_i^a + v_i + \theta_{it}. \tag{2}$$

It should be noted at this stage that, among the parameters of main interest, the within procedure permits estimation of only γ and β; while the between procedure permits estimation of only $\bar{\gamma}$ and $\bar{\beta}$. Of course these issues do not arise in conventional panel data estimation where it is typically assumed that $\gamma = \bar{\gamma}$ and $\beta = \bar{\beta}$.[5]

[5]This is the hypothesis tested in the Hausman specification test for panel data models. Furthermore, this constraint is precisely what makes the Hausman and Taylor (1981) instrumental variables procedure possible, where the procedure involves the use of the time-average of variables included in the model that have both time and industry dimension as instruments for variables

Broadly speaking, our approach is to consider different variables (or sets of variables) as proxies for the best index of aggregate activity affecting productivity growth at the four-digit level. We first address the question of whether, in addition to the effects operative between the two-digit and aggregate levels found in Caballero and Lyons (1989, 1990), externalities are also operative between the two- and four-digit levels. By including a measure of sectoral activity in addition to aggregate activity we can make some progress in determining the degree to which external effects are a localized phenomenon. We then consider more explicitly the linkages across industries. For example, if the externalities are working through the intermediate goods channel then it would be more appropriate to weight the aggregate activity variable for each industry according to the share of materials *received* from other industries, rather than the simple aggregate. In contrast, if the externality derives from aggregate demand then weighting the aggregate activity variable according to where output is *going* is more appropriate. Implications of the transactions externality are less clear cut; both input weights and output weights are likely to be relevant, given that transactions occur both on the incoming side of operations (procurement) and on the outgoing side.

3 EMPIRICAL EVIDENCE

3.1 WITHIN ESTIMATION

Table 1 presents a first look at the within estimates for equation (2). The first two columns of the table present the results for the model using OLSQ (ordinary least squares) and 2SLS (two-stage least squares) with both a sectoral (two-digit) externality, denoted by a subscript s, and a manufacturing-wide externality, denoted by a subscript a. In each case the externality is identified with the growth rate at the corresponding level, and γ is restricted across all industries.[6] Irrespective of the

with industry but no time dimension.

[6]The instruments include: the percentage change in defense expenditures, its lagged value, a dummy reflecting the political party of the president, its lagged value, the lagged percentage change

method of estimation, the measure of internal returns to scale is very close to one.

As for the external effects measures, it would appear that closeness, as measured by SIC industry definitions, is relevant: both β_s and β_a are significant and positive, suggesting that intra-industry activity levels, as captured by β_s, provide external economies beyond those deriving from aggregate activity levels.

Columns 3 through 8 present the results for the cases in which we adjust the weightings for the sectoral and aggregate activity levels according to input-output relationships.[7] The striking result here is that regardless of whether input or output weights are used, the incremental importance of sectoral growth vanishes. Columns 7 and 8 also demonstrate that when all four of the weighted aggregates —two sectoral and two manufacturing-wide— are included in the same regression the output channel is nearly twice as strong, though both the input-weighted and the output-weighted manufacturing-wide aggregates are significant.[8]

This table also demonstrates that once economically meaningful input-output relationships are taken into account, the 2SLS procedures are not essential for the issues addressed here; for computational simplicity, from now on we proceed with OLSQ only.[9]

Table 2 incorporates the findings of the previous table, and extends the results in several directions. Column 1 presents a parsimonious version of the preferred estimates in Table 1, while column 2 adds a set of time dummies to remove aggregate business cycle fluctuations.[10] Though the size of the output-weighted externality

in the ratio of the price of oil to the price of durables, the lagged percentage change in the ratio of the price of oil to the price of non-durables, the lagged percentage change in the activity level (cost-share-weighted inputs) of durables industries, and the lagged percentage change in the activity level of non-durables industries.

[7]The appendix describes the construction of these weights from the 1977 Input-Ouput Structure of the U.S. economy.

[8]If γ is left unconstrained up to the two-digit level the results tell the same story that appears in Table 1, namely that within-industry activity levels per se are not important in the transmission of externalities, and that output linkages appear to be more important than input linkages. The median γ's remain in the neighborhood of constant returns to scale, with a standard deviation of the estimates across industries of about 20% (OLSQ). See Table 6.

[9]In Table 1, the reported standard errors under 2SLS are not the correct ones since they do not take into consideration the two-stage nature of the procedure.

[10]The time dummies, combined with the restriction that coefficients are the same across indus-

Table 1: First Look, Within Estimates

	dx		dx^{IW}		dx^{OW}		(dx^{IW}, dx^{OW})	
	OLSQ	2SLS	OLSQ	2SLS	OLSQ	2SLS	OLSQ	2SLS
γ	1.02 (.015)	1.05 (.014)	1.03 (.015)	1.06 (.014)	1.01 (.015)	1.03 (.014)	1.00 (.016)	1.02 (.014)
β_s	.13 (.037)	.23 (.028)	— —	— —	— —	— —	— —	— —
β_a	.45 (.053)	.28 (.034)	— —	— —	— —	— —	— —	— —
β_s^{IW}	— —	— —	-.02 (.034)	.02 (.030)	— —	— —	-.07 (.036)	-.02 (.032)
β_a^{IW}	— —	— —	.43 (.047)	.42 (.038)	— —	— —	.20 (.052)	.18 (.043)
β_s^{OW}	— —	— —	— —	— —	.04 (.035)	.03 (.030)	.02 (.040)	-.03 (.035)
β_a^{OW}	— —	— —	— —	— —	.41 (.038)	.44 (.032)	.36 (.040)	.34 (.034)
$\overline{R}^2$	.36	—	.36	—	.36	—	.37	—

Notes: Standard errors in parentheses. All variables are demeaned; a "—" denotes an irrelevant entry. The variable y is the log-first-difference of real value added; x_i is the log-first difference of an own input index; the superscripts IW and OW denote input- and output-weighted averages of other industries input changes, respectively, with a subscript s for other industries within the relevant two-digit sector, and the subscript a for the aggregate of all other industries.

Table 2: Summary Table, Within Estimates

	Manuf. VA		Expanded VA		Expan. Gr. Prod.	
	No T.D.	T.D.	No T.D.	T.D.	No T.D.	T.D.
γ	.999 (.015)	1.003 (.015)	1.007 (.016)	1.006 (.016)	1.096 (.007)	1.097 (.007)
β_a^{IW}	.145 (.040)	.161 (.050)	.032 (.053)	.004 (.065)	.033 (.023)	.019 (.029)
β_a^{OW}	.362 (.034)	.274 (.037)	.567 (.044)	.436 (.048)	.186 (.021)	.118 (.023)
$\overline{R}^2$	.37	.38	.37	.39	.75	.76

Notes: Standard errors in parentheses. The superscripts *IW* and *OW* denote input- and output-weighted, respectively. The expanded sector includes the activity of the nonmanufacturing sector as providing externalities to the manufacturing sector. The gross production columns use an aggregate activity measure including capital, labor, and materials inputs.

does decrease with the inclusion of the time dummies, both effects remain large and economically significant.

If transactions per se, sector-specific demand (the common effect of aggregate demand is removed by the time dummies), or both play a major role in boosting industry productivity, there is no reason, besides data availability, to close the model in manufacturing. In the next two columns of Table 2 we "expand" the model to include in our weightings the activity levels of nonmanufacturing suppliers and customers in the business sector.

The estimates suggest that once the customer weights are fully specified the

tries, remove entirely the possibility that the externalities are proxies for a common shock, even if these affect sectors differently (see Caballero and Lyons 1991).

input-weighted component of the externality vanishes. The effects appear to be tied wholly to the activity levels of the sectors an industry supplies, whether those sectors are principally within manufacturing, as would be the case for a materials or semi-finished goods industry, or whether the sectors are principally outside manufacturing, as in the cases of construction or transportation.

This set of results hints that there appears to be no evidence for the existence of fluctuations-oriented external effects deriving from either specialization of intermediate goods, or from in-bound transactions. Both of these channels would imply some effect coming from the input-weighted aggregates, yet we find none in the context of our expanded model.

The debate about the virtues and shortcomings of value-added models is an old one.[11] In the last two columns of Table 2 we reproduce our (expanded) results using gross production instead of value added in order to check whether there is any sensitivity along these lines. These columns demonstrate that the externalities remain highly significant and positive. It is also apparent, however, that some of the weight moves away from the externality to the own inputs coefficient; we suspect that this is partly an artifact of the way we construct our expanded gross-production external activity measures, which do not include materials (see the appendix).

3.2 Between Estimation

Table 3 presents the between estimates for the same models presented in Table 2. The three columns show a dramatic shift of the externality towards input-weighted measures of aggregate activity. With the expanded model and the gross production estimation the output-weighted activity level loses its significance completely. With the manufacturing model the output-weighted activity level comes out significant but negative. On the whole, then, the between results suggest that over longer horizons external effects are operating through intermediate goods linkages.

Conventional simultaneity bias, i.e. the correlation between own-input growth

[11] See Baily (1986) for a summary of the central issues.

Table 3: Summary Table, Between Estimates

	Manuf. VA	Expanded VA	Expan. Gr. Prod.
Const	.013 (.001)	.011 (.002)	-.001 (.002)
γ	1.122 (.041)	1.115 (.041)	1.087 (.024)
$\bar{\beta}_a^{IW}$	.291 (.094)	.230 (.126)	.285 (.082)
$\bar{\beta}_a^{OW}$	-.212 (.086)	-.071 (.095)	.077 (.066)
$\overline{R}^2$	.67	.65	.85

Notes: Standard errors in parentheses. The superscripts *IW* and *OW* denote input- and output-weighted, respectively. The expanded sector includes activity of the nonmanufacturing sector as providing externalities to the manufacturing sector. The gross production columns use an aggregate activity measure using capital, labor, and materials inputs.

and unobserved technological progress, is likely to be a more important issue in the between dimension of the data. We address this in two ways. First, we consider instrumental variable procedures. Second, we consider whether it is plausible that, if simultaneity were in fact the whole story, the input-weighted activity measure would so completely dominate the output-weighted measure.

In pursuing the instrumental variables procedures, the instruments we use are the average energy to shipments ratio, the average capital-labor ratio, the average growth rate of the capital-labor ratio, the average level of the materials-shipments ratio, the average growth rate of the materials-shipments ratio, and the average growth rate of the shipments deflator-oil price ratio. For each industry, we created a weighted average of these cross-sectional variables using the input and output weights. Using these instruments, the input-weighted aggregate activity measure is significantly positive (0.89 with a standard error of 0.23), γ is about unity (1.04 with a standard error of 0.16), and the output-weighted aggregate is insignificant (0.13 with a standard error of 0.25). Overall, then, the IV results are not substantively different from those generated using OLSQ.

As a final indicator of whether the between results might be largely due to simultaneity bias, we consider the correlations between the two aggregate activity variables, input- and output-weighted, and own-industry inputs. Given that our estimates give full weight to the input-weighted measure, a simultaneity problem is unlikely to be the complete explanation if the input-weighted measure does not have a higher covariance with own-industry inputs than the output-weighted measure. In fact, the correlation between the input-weighted measure and own-industry inputs is lower than the correlation between the output-weighted measure and own-industry inputs (0.24 vs. 0.35) with about the same variance of input- and output-weighted measures. Moreover, because there is very little correlation between the input- and output-weighted measures themselves, it is not possible to resort to the argument that the two variables are simply highly colinear, and that it happens to be that the input-weighted measure gets all the significance. This is confirmed by running regressions including only one of the externality regressors at a time; we find that only the input-weighted externality shows up significant, with point estimates very similar to those obtained when both externality regressors are included.

3.3 Full Model

Here we impose the constraint that the degree of internal returns to scale is the same over shorter and longer horizons. Table 4 presents the basic results. They do not change the conclusions from the earlier tables: the within estimates put nearly full stress on the output weights, whereas the between estimates put nearly full stress on the input weights. Interestingly, the negative between effect of output-weighted externalities in the manufacturing sector is no longer significant. As before, inclusion of time dummies lowers the cyclical externality but it still remains large and significant.[12]

3.4 Capacity Utilization

An important consideration in analyzing the results presented above is the potential role of excess capacity, either in terms of labor, capital, or both (Gordon 1990). Although one would expect capacity utilization to manifest itself mainly through its effect on the estimated internal scale elasticity (see Caballero and Lyons 1989), it is still possible that measurement problems could generate spurious correlation with our aggregate activity variables. To address this we made various attempts to purge the input data of changes in utilization.

First, the index of capacity utilization constructed by the Federal Reserve Board is included as an additional regressor. Because the index is only available at the two-digit level, we use the same two-digit index for each of the four-digit industries within the relevant sector. As rows 1, 4 and 7 in Table 5 demonstrate, the coefficient on this measure (FRB) is insignificant in all but one case (row 1), where it is quite

[12]The magnitude of the fall in the externality coefficient is a rough indicator of the magnitude of common shocks.

Table 4: Summary Table, Mixed Within-Between Estimates

	Manuf. VA		Expanded VA		Expan. Gr. Prod.	
	No T.D.	T.D.	No T.D.	T.D.	No T.D.	T.D.
Const	.013 (.002)	.021 (.006)	.010 (.003)	.018 (.006)	-.001 (.002)	.014 (.004)
γ	1.009 (.015)	1.013 (.015)	1.016 (.015)	1.016 (.015)	1.096 (.007)	1.096 (.007)
β_a^{IW}	.139 (.040)	.156 (.050)	.026 (.054)	-.002 (.066)	.034 (.023)	.019 (.029)
β_a^{OW}	.358 (.035)	.270 (.037)	.562 (.044)	.431 (.049)	.186 (.022)	.118 (.023)
$\bar{\beta}_a^{IW}$	.327 (.119)	.326 (.117)	.266 (.158)	.267 (.156)	.281 (.101)	.281 (.100)
$\bar{\beta}_a^{OW}$	-.134 (.104)	-.136 (.103)	-.008 (.116)	-.008 (.114)	.070 (.078)	.070 (.077)
$\overline{R}^2$	.38	.40	.39	.40	.76	.76

Notes: Standard errors in parentheses. The superscripts *IW* and *OW* denote input- and output-weighted, respectively. The expanded sector includes activity of the nonmanufacturing sector as providing externalities to the manufacturing sector. The gross production columns use an aggregate activity measure using capital, labor, and materials inputs. No T.D.: without time dummies. T.D.: with time dummies.

Table 5: Capacity Utilization Adjustment

Model	γ	β_a^{IW}	β_a^{OW}	$\bar{\beta}_a^{IW}$	$\bar{\beta}_a^{OW}$	$\dot{CU}$	$\bar{CU}$
Manuf. VA	1.01	.15	.26	.33	-.13	.04	-.01
FRB	(.02)	(.05)	(.04)	(.12)	(.10)	(.02)	(.02)
Manuf. VA	.92	.18	.28	.35	-.08	—	—
AGH	(.01)	(.05)	(.04)	(.12)	(.10)	—	
Manuf. VA	1.06	.16	.28	.31	-.17	-.27	.26
AGH	(.02)	(.05)	(.04)	(.12)	(.10)	(.03)	(.51)
Expanded VA	1.02	-.00	.42	.26	.02	.03	-.02
FRB	(.02)	(.07)	(.05)	(.16)	(.12)	(.02)	(.02)
Expanded VA	.92	.07	.43	.28	.07	—	—
AGH	(.01)	(.06)	(.05)	(.16)	(.12)	—	—
Expanded VA	1.06	-.00	.44	.25	-.04	-.27	.25
AGH	(.02)	(.07)	(.05)	(.16)	(.11)	(.03)	(.48)
Expan. Gr. Prod.	1.09	.02	.12	.26	.09	-.01	-.02
FRB	(.01)	(.03)	(.02)	(.10)	(.08)	(.01)	(.01)
Expan. Gr. Prod.	1.08	.03	.11	.29	.08	—	—
AGH	(.01)	(.03)	(.02)	(.10)	(.08)	—	—
Exan. Gr. Prod.	1.10	.02	.13	.28	.06	-.09	.30
AGH	(.01)	(.03)	(.02)	(.10)	(.08)	(.02)	(.30)

Notes: Standard errors in parenthesis. FRB is Federal Reserve Board measure of Capacity Utilization. AGH is Abbott, Griliches & Hausman proxy for capacity utilization, used either to adjust capital in the input measure, *or* as a separate regressor. $\dot{CU}$ denotes the within regressor while $\bar{CU}$ denotes the between regressor.

small and only marginally significant. More important, its inclusion does not alter any of the other parameters.

Next, we construct an index of capacity utilization based on the ratio of hours per worker to peak hours per worker in that industry, as suggested by Shapiro (1989) and Abbott, Griliches and Hausman (1988), henceforth denoted AGH. The capital stock is then multiplied by this rate to proxy the effective service flow from capital, or capital utilization. This adjustment lowers the estimate of the returns to scale parameter to slightly above 0.9 (see Jorgenson and Griliches 1967), but leaves the external effects unchanged (rows 2, 5 and 8). Instead of adjusting the capital stock, we also tried the index as an additional regressor; again the external effects were not substantively changed (rows 3, 6 and 9).

4 CONCLUSIONS

In this paper we propose a framework to discriminate between broad classes of external effects in an integrated manner. Overall, our results provide evidence that both fluctuations-oriented and growth-oriented external economies are present within U.S. manufacturing.

With respect to the fluctuations-oriented externalities, those which are more likely to be operative over shorter horizons, our results indicate that the linkage between an industry and its *customers* is the overriding factor in the transmission of external effects. We find that the output-weighted aggregates remain significant throughout our within estimation, regardless of whether gross production or value added is used. This is true even in the case in which we remove purely aggregate movements by including time dummies. Moreover, in the context of the expanded model, which includes demand categories outside of manufacturing, the output-weighted aggregate becomes the sole indicator of external effects. In addition, the magnitude of the effect is not a function of whether the expanding industries are within a given two-digit sector or are outside of it. Once the interindustry linkage is fully specified the measure of closeness in and of itself does not appear to be relevant.

With respect to the growth-oriented externalities, our between estimates indicate that the linkage between an industry and its *suppliers* becomes the dominant factor over longer periods of time. This result suggests that over longer horizons, the role of intermediate goods is important in accounting for multifactor productivity growth. This role for intermediates might be coming from either further specialization or the embodiment of knowledge and increased quality derived therefrom.

A Robustness

In this section we consider possible alternative specifications for our models, together with some extensions. The results from these various specifications are displayed in Tables 6 and 7.

A.1 Sectoral Results

It is not, a-priori, obvious at which level of aggregation it is valid to restrict the parameters of the production technology. As was shown above, for the purpose of identifying the level of aggregation relevant to external effects, closeness in the input-output sense is much more important than closeness in SIC classification. For the internal scale elasticity, the appropriate level of aggregation for the parameter restrictions is the level at which one can be comfortable in assuming common technology. The position that the parameter γ is the same for all 450 four-digit industries is obviously not defensible. However, what is relevant here is the degree to which the conclusions presented earlier are sensitive to this restrictive assumption.

To this end, we estimated the within models with γ restricted and β's varying (columns 1 and 2 of table 6), with β restricted and γ's varying (columns 3 and 4), and finally with the γ's and β's allowed to vary across two-digit industries. As table 6 demonstrates, the median internal and external effects from the within model are virtually the same as in the restricted models. Although the parameters do vary considerably across sectors, the conclusions regarding the relative importance of different external effects carry through.

A.2 Problems with Non-Production Workers and Materials

Expanding the basic model, to allow for external effects originating in nonmanufacturing sectors, introduces some inconsistencies in the treatment of own inputs vs. aggregate activity measures. The aggregate activity measures used in this paper are some weighted average of other sectors' input growth rates. The inconsistencies arise through differences in data availability for manufacturing vs. nonmanufacturing sectors. Two differences should be noted in the creation of input growth

Table 6: Sectoral γ's and β's, Within Estimates

	γ Restr.		β's Restr.		No Restr.	
	no TD	TD	no TD	TD	no TD	TD
γ	.99 (.02)	.99 (.02)	— —	— —	— —	— —
γ_{median} σ_γ	— —	— —	1.04 .22	1.05 .23	1.02 .20	1.03 .21
β_a^{IW}	— —	— —	.10 (.04)	.10 (.05)	— —	— —
$\beta_{a,median}^{IW}$ $\sigma_{\beta_a^{IW}}$	.07 .31	.15 .28	— —	— —	.05 .28	.11 .24
β_a^{OW}	— —	— —	.34 (.03)	.24 (.04)	— —	— —
$\beta_{a,median}^{OW}$ $\sigma_{\beta_a^{OW}}$	.32 .50	.28 .40	— —	— —	.32 .46	.26 .36
$\overline{R}^2$	.38	.39	.38	.40	.38	.40

Notes: Standard errors in parentheses. The superscripts IW and OW denote input- and output-weighted, respectively. All variables are demeaned. TD (with time dummies), no TD (without time dummies).

rates: 1) labor is measured in production worker hours for manufacturing, while it is measured in total hours for the nomanufacturing sectors, and 2) material inputs are not available for the nonmanufacturing sectors.

In the results reported earlier for the expanded value-added model, own inputs only include production worker hours and capital, whereas the aggregate activity measures include total worker hours and capital for the nonmanufacturing sectors. To assess whether this skews results, the first half of Table 7 reports on alternatives including non-production workers. The first three rows of the table show the within, mixed, and between estimates, respectively, for the non-expanded model. The own input index, and the weighted aggregate activity measure (limited to manufacturing industries), include production worker *hours*, non-production worker *employment*, and capital. The earlier results are substantively unchanged.

Since materials are not available for the nonmanufacturing sectors, the results reported in the text for the expanded gross production model use only capital and labor inputs to create the weighted aggregate activity measure for the nonmanufacturing sector, while capital, labor, and material inputs are used to create the weighted aggregate for manufacturing sectors. Naturally, the own input measure includes materials. As an alternative, we estimated the gross production model, with external effects only emanating from the manufacturing sector. Two sets of aggregate activity measures were created; one using capital, labor, and material inputs, the other only with capital and labor. The results of the within, mixed, and between estimates are shown in the bottom three rows of Table 7. As can be seen from the within estimates (the middle rows of the "Materials" section of the table), the output-weighted aggregate coefficient is reduced when materials are omitted, while the input-weighted measure and the own scale elasticity increase somewhat. We expect that a similar bias occurs in the expanded version of the model, where materials are omitted from the external effects of the nonmanufacturing sectors.

Table 7: Non-Production Workers and Gross Production Regressions

Model	Const	γ	β_a^{IW}	β_a^{OW}	$\bar{\beta}_a^{IW}$	$\bar{\beta}_a^{OW}$
Non-Prod	.00	.99	.18	.40	—	—
	(.00)	(.02)	(.04)	(.04)	—	—
	.01	1.00	.17	.40	.34	-.07
	(.00)	(.02)	(.04)	(.04)	(.12)	(.11)
	.01	1.13	—	—	.30	-.16
	(.00)	(.04)	—	—	(.09)	(.08)
Materials	.00	1.09	-.04	.11	—	—
w. Mat.	(.00)	(.01)	(.02)	(.02)	—	—
	.00	1.10	.05	.07	—	—
w/o Mat.	(.00)	(.01)	(.03)	(.02)	—	—
	.02	1.09	-.04	.11	.22	.11
w. Mat.	(.00)	(.01)	(.02)	(.02)	(.07)	(.06)
	.02	1.10	.05	.07	.19	-.01
w/o Mat.	(.00)	(.01)	(.03)	(.02)	(.07)	(.06)
	.00	1.08	—	—	.23	.10
w. Mat.	(.00)	(.02)	—	—	(.06)	(.06)
	.00	1.1	—	—	.19	-.01
w/o Mat.	(.00)	(.02)	—	—	(.06)	(.06)

Notes: Standard Errors in parentheses. Regressions include Time Dummies for within and mixed regressions. "Non-Prod" is the value added model, non expanded, including non-production workers in the own input and aggregate activity measures. The rows show the within, mixed, and between estimates in that order. "Materials" is the gross production model, non-expanded, with and without materials included in the aggregate activity measure for the manufacturing industries. The first two rows of estimates are for the within model, followed by the mixed and between models respectively.

B Data Description

The data sets used in this study are the Penn-Census-SRI (PCS) productivity data set, the input-output accounts for the U.S. economy, and two-digit production data used by Hall (1988,1990). The PCS data, with information for four-digit manufacturing industries from 1958 through 1986, is being maintained and updated by Wayne Gray. Documentation of this data can be found in Gray (1989). The inter-industry data is described in the BEA Survey of Current Business (1984), and reflects the 1977 input-output structure of the U.S. economy for 537 industry/commodity classes. The Hall data set contains production data for two-digit industries from 1953 through 1984 and is available from him on request.

The series used from the PCS data set are value added, production workers, production worker hours, real capital stock, production worker wages, the shipments deflator, and the investment deflator, for 450 four-digit manufacturing industries, as defined in the 1972 Standard Industrial Classification (SIC), for the years 1958 through 1986. Real value added is created by deflating value added with the shipments deflator for the corresponding four-digit industry. A discussion of the advantages and drawbacks of various deflators for value added can be found in Sims (1977).

The 'Make' and 'Use' tables from the 1977 input-output system are used to create an industry-by-industry direct-requirements matrix for the four-digit manufacturing and 2 digit nonmanufacturing industries. To this end, a concordance between the 537 BEA categories and the 450 four-digit manufacturing plus 10 two-digit nonmanufacturing sectors was applied to the computed 537x537 direct-requirements matrix.[13] The direct-requirements matrix has elements ij, which show the value of product from industry i, used as an intermediate material in industry j. To create an output-weighted aggregate activity index for industry i, one computes an output-weighted average of percentage changes in activity of all other industries which purchase product from industry i. The output-weight applied to industry j

[13] See Mattey (1990).

when creating the aggregate index for industry i, is the ijth-element of the matrix, divided by the sum of the ith-row. To get the input-weighted aggregate activity index for industry j, one computes a weighted average of the change in activity of the industries which deliver product to industry j. The weight applied to activity of industry i is the ijth-element divided by the sum of the jth-column of the direct-requirements table. A similar use of the interindustry flow matrix has been made by Terleckyj (1974), who constructs forward and backward linkages for the effects of R&D on productivity.

The Hall data set is used for creating instruments, a rental cost of capital, and for extending the sources of externalities to nonmanufacturing sectors. The eight instruments used in the 2SLS regressions include those used by Hall as well as some others: A dummy for the political party of the president, the lagged value for this dummy, the lagged percentage change in the ratio of the oil price to the price of nondurables, the lagged percentage change in the ratio of the oil price to the price of durables, the percentage change in defense expenditures, its lagged value, the lagged percentage change in activity in durables industries, and the lagged percentage change in activity in nondurables industries. Capital rental rates are computed with Hall's data as follows: $r = (\rho + \delta)\frac{1-c-\tau d}{1-\tau}p_k$, where ρ is the firm's real cost of funds, δ is the economic rate of depreciation, c is the effective rate of investment tax credit, d is the present discounted value of tax deductions for depeciation, τ is the corporate tax rate and p_k is the investment deflator. This deflator is available in the PCS data for each four-digit industry. The nonmanufacturing sectors which are included in the aggregates for the explanded model are: agriculture, mining, construction, transportation, utilities, communications, wholesale, retail, finance, and services. These data are available through 1984.

REFERENCES

1. ABBOTT, T.A. III, GRILICHES, Z., AND HAUSMAN, J.A.: "Short-run Movements in Productivity: Market Power versus Capacity Utilization," mimeo (1988).

2. ADAMS, J.D.: "Fundamental Stocks of Knowledge and Productivity Growth," *Journal of Political Economy* **98** (1990), 673–702.

3. BAILY, M.N.: "Productivity Growth and Materials Use in U.S. Manufacturing," *Quarterly Journal of Economics*, (1986), 185–195.

4. BARTELSMAN, E.J.: "Federally Sponsored R&D and Productivity Growth," Finance and Economics Discussion Series, #121, Board of Governors of the Federal Reserve System, (1990).

5. BARTELSMAN, E.J.: "R&D Spending and Manufacturing Productivity: An Empirical Analysis," Finance and Economics Discussion Series, #122, Board of Governors of the Federal Reserve System, (1990).

6. BARTELSMAN, E.J.: "Three Essays on Productivity Growth," unpublished Ph.D. Dissertation, Columbia University, (1991).

7. BENHABIB, J., AND B. JOVANOVIC : "Externalities and Growth Accounting," *American Economic Review* **81(1)**, (1991), 82–113.

8. BERNSTEIN, J.I., and M.I. NADIRI: "Interindustry R&D Spillovers, Rates of Return, and Production in High-Tech Industries," *American Economic Review, Papers and Proceedings* **78(2)**, (1988), 429–434.

9. BRESNAHAN, T: "Measuring Spillovers from Technical Advance," *American Economic Review* **76**, (1986), 741–755.

10. BUREAU of ECONOMIC ANALYSIS : "The Input-Output Structure of the U.S. Economy, 1977," *Survey of Current Business* **5**, (1984).

11. CABALLERO, R.J. AND R.K. LYONS : "The Role of External Economies in U.S. Manufacturing," Columbia mimeo, (1989).

12. CABALLERO, R.J. AND R.K. LYONS : "Internal Versus External Economies in European Industry," *European Economic Review* **34**, (1990), 805-830.

13. CABALLERO, R.J. AND R.K. LYONS : "The Evidence for External Economies: An Overview," Columbia mimeo, (1991).

14. COOPER, R. AND A. JOHN : "Coordinating Coordination Failures in Keynesian Models," *Quarterly Journal of Economics* **CIII** (1988), 441-465.

15. DIAMOND, P.: "Aggregate Demand Management in Search Equilibrium," *Journal of Political Economy* **90** (1982), 881–894.

16. DURLAUF, S.: "Locally Interacting Systems, Coordination Failure, and the Behavior of Aggregate Activity," Stanford University mimeo, (1990).

17. ETHIER, W.: "Internationally Decreasing Costs and World Trade," *Journal of International Economics* **9** (1979), 1-24.

18. ETHIER, W.: "National and International Returns to Scale in the Modern Theory of International Trade," *American Economic Review* **72**, (1982), 389-405.

19. GORDON, R.J.: "Are Procyclical Productivity Fluctuations a Figment of Measurement Error?" mimeo, October, (1990).

20. GRAY, W.B.: "Productivity Database," mimeo, (1989).

21. GRILICHES, Z. AND F. LICHTENBERG: "Interindustry Technology Flows and Productivity Growth: A Reexamination," *Review of Economics and Statistics* **61** (1984), 324–329.

22. HALL, R.E.: "The Relation Between Price and Marginal Cost in U.S. Industry," *Journal of Political Economy* **96**, (1988).

23. HALL, R.E.: "Temporal Agglomeration," NBER Working Paper #3143 (1989).

24. HALL, R.E.: "Invariance Properties of Solow's Productivity Residual," in P. Diamond, ed., *Growth/Productivity/Unemployment*, M.I.T. Press: Cambridge, MA, (1990), 71–112.

25. HALL, R.E. AND D.W. JORGENSON : "Tax Policy and Investment Behavior," *American Economic Review* **57** (1967), 391–414.

26. HAUSMAN, J.A. AND W.E. TAYLOR : "Panel Data and Unobservable Individual Effects," *Econometrica* **48** (1981), 1377-1398.

27. HAMMOUR, M.: "Social Increasing Returns in Macro Models with External Effects," Columbia University Wp # 461 (1990).

28. JAFFE, A.B.: "Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value," *American Economic Review* **75-5** (1986), 984–1001.

29. JORGENSON, D.W. AND GRILICHES, ZVI : "The Explanation of Productivity Change," *Review of Economic Studies* **34** (1967), 249–283.

30. JORGENSON, D.W. AND M.A. SULLIVAN : "Inflation and Corporate Capital Recovery," in *Depreciation, Inflation, and the Taxation of Income from Capital*, Charles R. Hulten (ed.), Washington, DC, Urban Institute (1981), 171-237.

31. MATTEY, J.P.: "Prices By Industry-Based Stage-of-Process," Economic Activity Working Paper Series, # 111, Board of Governors of the Federal Reserve System, (1990).

32. MILGROM, P. AND.J. ROBERTS: "Rationalizability, Learning, and Equilibrium in Games with Strategic Complementarities," Stanford University Working Paper, (1989).

33. Mohnen, P.: "New Technologies and Industry Spillovers," mimeo (1989).

34. MURPHY, K.M., A. SHLEIFER, AND R.W. VISHNY: "Industrialization and the Big Push," *Journal of Political Economy* **97** (1989), 1003–26.

35. ROMER, P.: "Increasing Returns and Long-Run Growth," *Journal of Political Economy* **94** (1986a), 1002–37.

36. ROMER, P.: "Increasing Returns, Specialization, and External Economies: Growth as Described by Allyn Young," Rochester Center for Economic Research Working Paper No. 64, (1986b).

37. ROMER, P.: "Crazy Explanations for the Productivity Slowdown," in *NBER Macroeconomics Annual 1987*, edited by Stanley Fischer, Cambridge: The MIT Press, (1987), 163–201.

38. ROSENBERG, N.: *Inside the Black Box: Technology and Economics*, New York: Cambridge University Press (1982).

39. SHAPIRO, M.D.: "Assessing Federal Reserve Measures of Capacity and Utilization," *Brookings Papers on Economic Activity* I (1989), 181–225.

40. SIMS, C.A.: "Remarks on Real Value Added," *Annals of Economics and Social Measurement* **6-1** (1977), 127–131.

41. TERLECKYJ, N.: "Effects of R&D on the Productivity Growth of Industries: An Exploratory Study," National Planning Association, Washington, D.C., (1974).