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PRODUCTIVITY AND R&D AT THE FIRM
LEVEL IN FRENCH MANUFACTURING

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Productivity and R&D at the firm level in French Manufacturing

ABSTRACT

In a companion study to that of Griliches and Mairesse for the United States, we have investigated the relationship between output, labor, and physical and R&D capital during the 1972-1977 period for a sample of 182 R&D performing firms in the French manufacturing industries. Our results are quite comparable to those obtained for the U.S. The relationship between firm productivity and R&D appears both strong and robust in the cross-sectional dimension of the data; it is less so in the time dimension. However, the within-firm estimates are still significant and of a likely order of magnitude. In this respect, they are more satisfactory than the U.S. ones. We show that this is largely due to a better measurement of the variables: (1) the fact that we can use a value-added measure of output instead of sales (or equivalently that we include materials among the factors of the production function); (2) the fact that we can correct the measures of labor, physical capital and output for the double counting or expensing out of the labor, capital and materials components of R&D expenditures.

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Introduction

       Following Griliches and Mairesse's study for the United States (this volume), we use a similar analysis to assess whether or not there exists a significant relationship between R&D expenditures and productivity performance at the firm level in French manufacturing. Our purpose is twofold: to check the type of results obtained by Griliches and Mairesse on their U.S. sample of firms doing R&D against a comparable sample of French firms and to set the stage for a careful comparison of industrial productivity growth in the two countries. The framework and data used are basically the same as in the U.S. study. We have, however, the advantage of being able to use value added which may be a more appropriate measure of production than sales. Moreover, having detailed information on R&D expenditures permits us to correct the measures of physical capital, labor, and production for the double counting or expensing out of R&D labor, capital, or materials. One important drawback of our study is the shorter period, 1972-77 as compared to 1966-77 in the U.S. study.

       On the whole, our main findings are quite close to the results obtained by Griliches and Mairesse. We come up with similar discrepancies between the total and within-firm estimates of the two parameters of main interest: the elasticities of physical and R&D capital stocks, α and γ, based on differences across firms and changes over time, respectively. However, due to better measures of the variables, the problem is much less serious than it could have been, and on the whole our estimates are statistically significant and of a likely order of magnitude.

       We describe our framework and data and present our main results in section I. We document and discuss the changes in our estimates due to our improved measures of variables in section II. In both sections, we systematically refer to Griliches and Mairesse and stress the various comparative aspects of the two studies.

I. Framework, Data and Main Results

A. Framework

Our basic model, as in Griliches and Mairesse, is the simple extended Cobb-Douglas production function, which can be written in logarithmic form as

$$v_{it} = a + \lambda t + \alpha c_{it} + \beta \ell_{it} + \gamma k_{it} + e_{it}$$

or

$$(v_{it} - \ell_{it}) = a + \lambda t + \alpha(c_{it} - \ell_{it}) + \gamma(k_{it} - \ell_{it}) + (\mu - 1)\ell_{it} + e_{it}.$$

The subscripts i, t refer to the firm i and the current year t; e is the error term in the equation; v, c, ℓ, and k stand for production (value added), physical capital, labor, and R&D capital, respectively; α, β, and γ are the parameters (elasticities) of interest; $\mu = \alpha + \beta + \gamma$ is the coefficient of returns to scale; and λ is the rate of disembodied technical change.

We follow the common practice in analyses of panel data by assuming that the error term e_{it} is composed of two components: a permanent effect specific to the firm u_i and a transitory effect w_{it}. Such a decomposition generates two types of estimates, which can be viewed as providing cross-sectional and time-series estimates, respectively: the between-firm estimates based on the firm-means $y_{i\cdot}$ and the within-firm estimates based on the deviations of the observations from the firm-means $(y_{it} - y_{i\cdot})$. The between-firm estimates are not affected by the biases due to possible correlations between the explanatory variables with the w_{it}'s (at least in a long enough sample), while the within-firm estimates are not affected by correlations with the u_i's. Both estimates should be consistent under the assumption of uncorrelated errors, while significant differences between them imply some sort of model misspecification. The least squares estimates based on the original observations y_{it}, the total estimates, differ very little from the between-firm estimates, since most of the variability in our data comes from the between-firm dimension rather

than from the within-firm dimension. Therefore, as in the U.S. paper, we shall report only on the total estimates and the within-firm estimates, and not also on the between-firm ones.

B. Data

Our sample is based primarily on the match of two different data sources: INSEE provided us with balance sheet and current account figures (from the SUSE files) while the Ministry of Research and Industry (DGRST and STISI) provided the R&D information (from the annual survey on company R&D expenditures). The size of the sample is larger than that of the U.S. sample: 182 firms against 133 for the complete U.S. sample, or 103 for the U.S. sample that is restricted to nonmerger firms. The study period, however, is much shorter: from 1972 to 1977, as compared with of 1966 to 1977 for the U.S. samples.

Like the U.S. sample, ours is very heterogeneous. This led us to divide it into two subsamples: so-called scientific firms belonging to the R&D intensive industries: chemicals, drugs, electronics and electrical equipment; and other firms belonging to the other manufacturing industries.

Our variables are defined and measured on a basis similar to Griliches and Mairesse; however, we have taken advantage of the additional information we had on materials and on the components of R&D expenditures. We measure production by deflated value-added V rather than by deflated sales. We also correct our value-added variable by adding back the materials consumption component of R&D expenditures, which is normally expensed out in current accounts. Labor L is measured by the number of employees, physical capital stock C by gross-plant adjusted for inflation, and R&D capital stock K by the weighted sum of past R&D expenditures using a constant rate of obsolescence of 15 percent per

year. Both our labor and physical capital stock variables are corrected for
the double counting of R&D already included in the R&D capital stock variable.
The available number of R&D employees is thus simply substracted from the total
number of employees, while the part of physical capital stock used in R&D is
computed on the basis of the average ratio of the physical investment component
of R&D expenditures to total R&D expenditures and is likewise substracted.

Detailed information on the sample and the variables is given in Appen-
dix A; see in particular Appendix Tables A1 and A2 which are comparable to the
corresponding ones in the U.S. study. The much more rapid productivity growth
and higher R&D intensiveness of the scientific firms subsample (than for the
other firms subsample) are remarkable in both countries. Since our study period
is shorter, the within-firm variability is even a smaller proportion of the
total variability (about 1 percent for levels, and 5 to 10 percent for ratios)
than is the case in the U.S. sample. Note also that the French firms are much
smaller in size than their U.S. counterparts: an average of 1500 employees in
French firms as against 10,000 employees in U.S. firms.

C. Main Results

Our main results are presented in Table 1, again in a format com-
parable to the U.S. study: total and within-firm estimates of the production
function with and without R&D capital stock, assuming or not assuming constant
returns to scale, for all firms and for the scientific and other firms sepa-
rately.

The total estimates are quite satisfactory on the whole. The elasti-
city of physical capital α is perhaps somewhat too low but still of a likely
order of magnitude: about .20. In contrast, the elasticity of R&D capital

γ may be too high: about .20 for the scientific firms and .10 for the other firms. The returns to scale are not significantly different from unity. As could be expected from the average rates of productivity growth over our study period, the rate of disembodied technical change is quite high (3 percent) for the scientific firms, while it is actually negative (minus 2 percent) for the other firms.

The within-firm estimates tend to differ from the total ones, although not as much as in the U.S. study. When assuming constant returns to scale, both types of estimates are actually quite close, the only significant discrepancy being the higher within-firm estimate of α for the other firms. However, when we relax this assumption, just as in the U.S. case, we obtain lower estimates of α and γ with rather implausible decreasing returns to scale estimates.

II. Further Results

A. Value Added versus Sales

The use of gross output or sales S instead of value added, or, alternatively, the omission of materials M among the factors in the production function is one of the possible misspecifications and sources of bias stressed by Griliches and Mairesse. We are able to check with our data whether or not this makes a real difference. Table 2 gives the results of such comparisons for the scientific and other firms separately. The estimates on the first three lines are comparable to those in Table 1, except that we use sales instead of value added to measure output. In the estimates on the fourth line, materials are included as another factor of the Cobb-Douglas production function (with an elasticity δ).

The Griliches and Mairesse conjectures are verified by and large.
The total estimates using sales and omitting materials do not differ much from
those obtained with value added: the elasticity of R&D capital γ is practi-
cally unaffected, and returns to scale remain constant; however, the elasticity
of physical capital α tends to be significantly higher. When materials are
included, we find a plausible total estimate of the elasticity of materials δ
of .5, while the estimate of the elasticities of physical and R-D capital
α and γ are multiplied approximately by a factor of $(1-\delta) \sim .5$ as expected.
The within-firm estimates with sales instead of value added also are similar
when we impose constant returns to scale. However, if we do not, large discre-
pancies occur; we get even more sharply decreasing returns to scale (.5 instead
of .75), while the estimate of γ collapses for the scientific firms (.03) and
also that of α for the other firms (.04). When materials are taken into
account, the within-firm estimates are much improved; they become coherent again
with the within-firm estimates obtained using value added (granted the multi-
plicative factor $1-\delta$) as well as closer to the total estimates.

Our results confirm that the omission of materials in the sales spe-
cification affects especially the within-firm estimates, which is related to the
fact that in the short-run materials usage varies much less than proportionally
with changes in output and other inputs. The value-added specification has the
advantage of being largely immune to such problems (implying in a sense that out-
put and materials vary proportionally). It is clear, however, that the sales spe-
cification duly including materials and the value-added specification both suffer
from other problems since they still give rise to estimates of large decreasing
returns to scale in the within-firm dimension. One possible explanation is the
disregard for the simultaneity in the determination of output and labor, and

also materials. Griliches and Mairesse have investigated this second possibi-
lity by estimating what they call the semireduced-form model, and we consider it
too.

B. Semi-Reduced Form Estimates Versus Production Function Estimates

If we assume with Griliches and Mairesse that firms maximize their
short-run profits and are price-takers on competitive markets, and if we lump
together the unobserved factor price variables with the errors in the equations,
we derive a "semi-reduced form model" expressing the relationship between the
endogenous output and labor variables only in terms of the predetermined physi-
cal and R&D capital stocks. Using value added and omitting materials (and
ignoring also constants, time trends or year dummies), we get:

$$v_{it} = \alpha' c_{it} + \gamma' k_{it} + e'_{it}$$

(I)

$$\ell_{it} = \alpha' c_{it} + \gamma' k_{it} + e''_{it}$$

where $\alpha' = \alpha/(1 - \beta)$ and $\gamma' = \gamma/(1 - \beta)$.

If we use sales rather than value added and include materials as
another variable factor, we have the same two equations for output and labor
(with sales instead of value added) and a parallel third equation for materials:

$$s_{it} = \alpha' c_{it} + \gamma' k_{it} + e'_{it}$$

(II) $$\ell_{it} = \alpha' c_{it} + \gamma' k_{it} + e''_{it}$$

$$m_{it} = \alpha' c_{it} + \gamma' k_{it} + e'''_{it}$$

where $\alpha' = \alpha/(1 - \beta - \delta)$ and $\gamma' = \delta/(1 - \beta - \delta)$.

Note that if this last system of equations holds, it implies that materials vary proportionally to sales, and hence that the value-added equation of the first system and the first system itself will also be verified. That is the elasticities for value added α, β and γ will be equal to the corresponding ones for sales multiplied by $1/(1 - \delta)$, and the reduced-form coefficients in the first system $\alpha/(1 - \beta)$ and $\gamma/(1 - \beta)$ will be equal to the ones in the second system $\alpha/(1 - \beta - \delta)$ and $\gamma/(1 - \beta - \delta)$.

Unconstrained and constrained total and within-firm estimates of the two semi-reduced form models using value added or sales are given in Table 3 for the scientific and the other firms separately. The corresponding estimates, α' and γ', in the various equations are rather close. Although most differences appear statistically significant given the large number of observations, constraining the coefficients to be equal entails only a very small loss of fit. The within-firm estimates of the materials equation are the most out of line, and also the poorest looking ones. All other estimates (i.e. the within-firm estimates of the other equations, and the total estimates of all the equations) are coherent enough with the direct estimates of the production function (given in tables 1 and 2).

The total estimates of the research capital coefficient γ' are all very significant and large; compared to the estimates of the physical capital coefficient α', they indicate that the relative magnitude of the two capital elasticities $\gamma/\alpha (= \gamma'/\alpha')$ is about two-thirds for the scientific firms and one-third for the other firms. This is somewhat small but also more reasonable than what we get from the direct estimates. Taking for example the true elasticity of labor β to be .6 in terms of value added, we obtain indeed very sensible numbers for α and γ: respectively .22 and .13 for the scientific firms, and .26 and .09 for the other firms.

The within-firm estimates of the research and physical capital coefficients are much smaller than the corresponding total estimates, and they also indicate a smaller relative magnitude for the research capital elasticity: about 30 to 40 percent for the scientific firms and 15 to 20 percent for the other firms. Thus, the absolute size of the within-firm estimates is also a problem for the semi-reduced form model and the discrepancy between these estimates and the total estimates remains. The fact that the estimated sum $(\alpha + \gamma)/(1 - \beta)$ is only about .4 to .5 in the within-firm dimension, while it is about .9 in the total dimension, is the equivalent of the finding of decreasing returns to scale for the production function within-firm estimates compared to the finding of nearly constant returns to scale in the total estimates. The same pattern is also observed in the U.S. study, but to a lesser extent: the semi-reduced form within-firm estimates are much better looking than the production function within-firm estimates.

On the whole, the semi-reduced form estimates do confirm the direct production function estimates, but, contrary to what could be hoped, they do not

constitute a major improvement. Clearly the simultaneity between output and labor is only one source of trouble. There are other problems which may affect both types of estimates. The omission of labor and capital intensity of utilization variables (such as hours of work per employee) in the production function considered by Griliches and Mairesse is presumably a very important one. The failure of the assumption of competitive markets and errors in the variables are two other possibilities also suggested by them. In what follows we are able to show that the measurement problem of the double counting of R&D matters a lot.

C. Correcting for The Double Counting of R&D

The Griliches and Mairesse's study, as well as the other studies of the contribution of R&D to productivity, suffers from the fact that R&D labor and physical capital are normally counted twice, once in the available measures of labor and physical capital and again in the measure of R&D capital stock. When a value-added measure is used for output, it also suffers from the fact that R&D expenditures (due to special fiscal rules in favor of R&D spending), are treated as intermediate inputs and are expensed out. This is true for materials used in R&D activities in France and for all R&D expenditures in the U.S. These problems are generally overlooked for lack of information to make the necessary adjustments. At best it is considered that the marginal product or rate of return ρ, which derives from the estimated elasticity of R&D γ in the production function, should be interpreted as the "net rate of return to R&D above and beyond its normal remuneration" (Griliches 1979). For our sample of firms, we can illustrate the importance of correcting the different variables for the double counting of R&D and we can verify the excess return interpretation. We

find that such interpretation is roughly valid for the total (or between-firm) estimates in the cross-sectional dimension of the data, but not for the within-firm estimates in the time dimension of the data. Both types of estimates are biased downward in the absence of correction, but in a rather untypical fashion the total estimates are much more affected than the within-firm estimates. We document these findings in Table 4; we also attempt to rationalize them in Appendix B.

Following Schankerman (1981), the biases due to R&D double counting and expensing out can be analyzed in terms of the following omitted variables in the production function: $(v'-v)$, $-\alpha(c'-c)$ and $-\beta(\ell'-\ell)$, where $(v'-v)$, $(c'-c)$ and $(\ell'-\ell)$ are the log differences of the uncorrected and corrected measures of value added, physical capital and labor. These three corrections are approximately -3, 5 and 10 percent respectively in our sample of scientific firms and -1, 1, and 3 percent for the other firms. Using the appropriate auxilliary regressions, the overall biases (i.e. the differences between the estimates based on the uncorrected and corrected measures) can be decomposed into three components corresponding to the three corrections for R&D materials, capital, and labor. Table 4 gives the overall biases and their components for the scientific and other firms separately. These numbers correspond to the estimates we get when we impose constant returns to scale; but they are practically unchanged if we do not.

In spite of the limited magnitude of our corrections for R-D double counting, the overall biases in the estimated elasticity of R&D capital γ are quite sizeable. On the other hand, the biases in the estimates of the

elasticity of physical capital α (and also of λ and β, or $\mu-1$) are relatively

small. The total estimates of γ are increased from about .10 to .20 (a

doubling) and from .09 to .12 for the scientific and other firms respectively,

while the within-firm estimates rise from .17 to .23 and .06 to .08 respec-

tively. The discrepancy between the within-firm and total estimates for the

scientific firms thus nearly vanishes. It is interesting to note that all three

γ-bias components are always negative and that they tend to be larger when the

corresponding corrections are more substantial, i.e. for the scientific firms

compared to the other firms and for the R&D labor correction compared to the

other two.

Summary and Conclusion

In a companion study to that of Griliches and Mairesse for the United States, we have investigated the relationship between output, labor, and physical and R&D capital during the 1972-1977 period for a sample of 182 R&D performing firms in the French manufacturing industries. Our results are quite comparable to those obtained for the U.S. The relationship between firm productivity and R&D appears both strong and robust in the cross-sectional dimension of the data; it is less so in the time dimension. However, the within-firm estimates are still significant and of a likely order of magnitude. In this respect, they are more satisfactory than the U.S. ones. We show that this is largely due to a better measurement of the variables: (1) the fact that we can use a value-added measure of output instead of sales (or equivalently that we include materials among the factors of the production function); (2) the fact that we can correct the measures of labor, physical capital and output for the double counting or expensing out of the labor, capital and materials components of R&D expenditures. As in the U.S. study, the "semi-reduced form" estimates which allow for simultaneity in the determination of output, labor and also materials agree with the production function direct estimates and confirm the importance of R&D capital relative to physical capital. However, both specifications yield rather implausible decreasing returns to scale estimates in the within-firm dimension. This is a pervasive problem in this type of work which needs to be solved before we shall be able to reconcile our cross-sectional and time-series results completely.

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Table 1: Production Function Estimates

for All Firms, and Scientific and Other Firms Separately

	Total Regressions						Within-Firm Regressions					
	α	Y	μ-1	λ	R²	MSE	α	Y	μ-1	λ	R²	MSE
All Firms (182)	.182 (.018)			.019 (.007)	.105	.1326	.392 (.042)			.007 (.004)	.165	.0219
	.213 (.013)	.209 (.007)		.005 (.005)	.512	.0724	.333 (.046)	.114 (.035)		.003 (.004)	.172	.0217
	.220 (.013)	.203 (.007)	-.018 (.006)	.005 (.005)	.516	.0719	.249 (.050)	.050 (.039)	-.228 (.060)	.015 (.005)	.183	.0215
Scientific Firms (98)	.273 (.020)			.039 (.008)	.287	.1106	.351 (.050)			.034 (.005)	.348	.0201
	.237 (.017)	.206 (.014)		.030 (.007)	.489	.0794	.232 (.055)	.229 (.048)		.029 (.005)	.372	.0194
	.237 (.017)	.206 (.014)	-.001 (.009)	.030 (.007)	.489	.0795	.152 (.060)	.144 (.054)	-.243 (.074)	.042 (.006)	.383	.0190
Other Firms (84)	.134 (.020)			-.008 (.006)	.086	.0568	.412 (.067)			-.023 (.005)	.071	.0196
	.175 (.018)	.116 (.010)		-.019 (.006)	.288	.0443	.371 (.071)	.079 (.047)		-.027 (.005)	.076	.0195
	.189 (.019)	.114 (.010)	-.018 (.007)	-.018 (.006)	.297	.0439	.268 (.080)	.027 (.050)	-.245 (.090)	-.015 (.007)	.090	.0193

Table 2: Production Function Estimates

Using Sales Instead of Value-Added and Excluding or Including Materials:

Scientific and Other Firms Separately

	Total Regressions							Within-Firm Regressions						
	α	γ	δ	$\mu-1$	λ	R^2	MSE	α	γ	δ	$\mu-1$	λ	R^2	MSE
Scientific Firms (98)	.391 (.026)				.015 (.011)	.293	.1854	.446 (.041)				.011 (.004)	.342	.0137
	.355 (.024)	.199 (.019)			.006 (.010)	.404	.1565	.341 (.045)	.200 (.040)			.007 (.004)	.369	0131
	.368 (.024)	.176 (.019)		-.061 (.012)	.007 (.009)	.430	.1501	.181 (.047)	.028 (.043)		-.491 (.058)	-.032 (.005)	.437	.0117
	.123 (.012)	.143 (.009)	.535 (.012)	-.021 (.006)	.014 (.004)	.877	.0324	.128 (.034)	.083 (.031)	.404 (.017)	-.160 (.044)	.021 (.003)	.710	.0061
Other Firms (84)	.263 (.030)				-.012 (.009)	.131	.1257	.341 (.060)				-.016 (.005)	.062	.0157
	.291 (.030)	.093 (.016)			-.019 (.009)	.187	.1179	.248 (.063)	.177 (.041)			-.022 (.005)	.096	.0152
	.289 (.031)	.093 (.016)		.002 (.012)	-.019 (.009)	.187	.1181	.038 (.068)	.071 (.043)		-.497 (.077)	.000 (.006)	.166	.0140
	.137 (.016)	.058 (.008)	.486 (.013)	-.036 (.006)	-.006 (.005)	.797	.0296	.133 (.042)	.052 (.027)	.474 (.017)	-.158 (.049)	-.005 (.004)	.682	.0050

Table 3: Semireduced-Form Equations Estimates –

Scientific Firms and Other Firms Separately

		Total Regressions			Within-Firm Regressions		
		α'	β'	System R^2	α'	β'	System R^2
Scientific Firms (98)	Sales	.601 (.018)	.284 (.020)	.796	.286 (.046)	.068 (.044)	.252
	Materials	.697 (.028)	.173 (.030)		.196 (.076)	-.111 (.073)	
	Value Added	.565 (.017)	.358 (.018)	.844	.314 (.059)	.204 (.056)	.304
	Labor	.588 (.022)	.273 (.024)		.350 (.040)	.132 (.038)	
	Constrained I	.566 (.017)	.353 (.018)	.839	.341 (.037)	.149 (.035)	.303
	Constrained II	.552 (.016)	.336 (.017)	.788	.325 (.034)	.107 (.032)	.244
Other Firms (84)	Sales	.712 (.017)	.204 (.017)	.848	.210 (.064)	.098 (.044)	.105
	Materials	.786 (.027)	.196 (.027)		-.006 (.105)	.069 (.072)	
	Value Added	.653 (.013)	.236 (.014)	.898	.469 (.075)	.058 (.052)	.134
	Labor	.683 (.015)	.179 (.015)		.437 (.042)	.067 (.029)	
	Constrained I	.660 (.013)	.223 (.013)	.894	.442 (.040)	.065 (.028)	.133
	Constrained II	.674 (.013)	.195 (.014)	.843	.396 (.039)	.077 (.027)	.093

*
Constrained I estimates assume equal coefficients in the value added and labor
equations. Constrained II estimates assume equal coefficients in the sales,
materials, and labor equations. The system-wide R^2 given are those of the
unconstrained and constrained systems of equations.

Table 4: Production Function Estimates with Uncorrected Measures and Approximate Decomposition of the Overall Biases Due to Expensing Out R&D Materials and Double Counting R&D Capital and Labor - Scientific and Other Firms Separately*

	Total Regressions					Within Regressions				
	α	γ	λ	R^2	MSE	α	γ	λ	R^2	MSE
Scientific Firms (98)										
Estimates with Uncorrected Measures	.267 (.017)	.107 (.014)	.036 (.007)	.414	.0743	.217 (.060)	.170 (.052)	.035 (.005)	.362	.0199
Overall Biases	.030	-.099	.006	-	-	-.015	-.059	.006	-	-
Due to: R&D Materials	.013	-.030	.002	.343	.0012	-.008	-.026	.003	.028	.0006
R&D Capital	.010	-.012	.000	.398	.0034	.007	-.008	.000	.160	.0001
R&D Labor	.013	-.048	.003	.498	.0048	-.004	-.023	.002	.029	.0013
Other Firms (84)										
Estimates with Uncorrected Measures	.182 (.018)	.093 (.010)	-.018 (.006)	.240	.0440	.384 (.072)	.061 (.048)	-.027 (.006)	.072	.0197
Overall Biases	.006	-.023	.000	-	-	.013	-.018	.000	-	-
Due to: R&D Materials	.002	-.006	-.000	.302	.0001	.003	-.000	.001	.048	.0000
R&D Capital	.001	-.001	.000	.372	.0001	.004	-.004	.000	.330	.0000
R&D Labor	.004	-.015	.001	.506	.0005	.003	-.015	.001	.116	.0001

*The estimates of the biases due to R&D materials, capital and labor are the estimates of the auxilliary regressions on $(v'-v)$, $(c'-c)$ and $(\ell'-\ell)$ respectively multiplied by 1, $-\alpha$ and $-\beta$, where α and β are taken as the unbiased estimates from the production function using the corrected measures (i.e. the estimates in Table 1). The corresponding R^2 and mean square errors (MSE) are those of the auxilliary regressions. These numbers are given in the case of the production function with constant returns to scale; they are practically unchanged, however, if we do not impose this restriction, and the biases in the estimated returns to scale themselves are negligible.

APPENDIX A

Additional Information on the Sample, the Variables,

and Various Experiments

The construction of our sample is quite similar to that of the U.S. sample by Griliches and Mairesse. Based on the two-digit French NAP and U.S. SIC classification, the definition of the group of scientific firms is the same in the two countries; however, we do not have firms in the computer and instruments industries in the French sample. We preferred to exclude from our sample the firms belonging to the air-crafts, boats and space vehicles industry (10 of them); this is an extremely R&D intensive industry (with an average R&D to value-added ratio of 35 percent) but most of it is public financed (about 80 percent) contrary to the other R-D intensive industries. The group of other firms in the U.S. include some nonmanufacturing companies, and also petroleum refining or food processing companies, which we have not considered as part of manufacturing in constructing our sample. As it is, the French sample accounts for nearly one half of the total R&D expenditures performed by French firms, while the similar ratio is about one-third for the U.S. sample.

Actually, our sample is more comparable to the U.S. restricted sample, since we removed about 25 "merger firms" (or firms which we assumed to be such because they showed large jumps of more than 100 percent increase or 50 percent decrease in gross plant, sales and/or number of employees). Since our study period covered only six years, it was not possible for us to deal with such firms by distinguishing "premerger" and "postmerger" firms.

Our value-added measure is at "factor costs", that is after deduction of the value-added tax and it is adjusted for inventory changes. Materials are taken simply as total purchases. Computing a proxy for value added as sales minus purchases changed only slightly our within estimates. We have deflated value added, sales and materials by the relevant national account industry price indices (at the two-digit classification level). Using the gross output price indices (rather than the value-added ones) to deflate value added did not change our estimates.

In our data, the numbers of employees are generally given at the end of the year and not computed as yearly averages which is the case for the U.S. data. We used, therefore, the beginning of the year numbers (i.e. the lagged numbers), as is also done for the capital stock measures. Taking the end of year number of employees tended to deteriorate our within estimates. This is another indication that simultaneity between employment and output is one of the sources of discrepancy between the total and within estimates.

The adjustment for inflation of the gross plant book value is made on the basis of an estimated average age of capital and an assumed average service life of 16 years. The average age of capital is derived from the ratio of net plant to gross plant, this ratio being itself corrected to take into account that the fiscal lengths of life used to compute depreciation in France are much shorter than the actual service lives. Experiments using gross plant adjusted for inflation in various ways, or even without any adjustment, made only very little differences to our estimates, as was also the case in the U.S. study.

We have been able to obtain the (internal) R&D expenditures before 1972 and back to 1963 for most of the firms in our sample, by consulting original

listings of the first R&D surveys. Our R&D capital stock measures are thus constructed from the past R&D flows for a long enough presample period (at least 9 years). Again as in the U.S. study, alternative measures assuming 0 or 30 percent rate of obsolescence per year instead of 15 percent, or using quite different initial conditions in 1963, had only minor effects on the estimates and the quality of the fit.

In addition to information on the materials, wages and physical investment components of total R&D expenditures (and the number of R&D employees), which we used to correct our measures of value added, physical capital and labor for R&D expensing out and double counting, different definitions and measures of R&D are available: total expenditures (whether they are financed by the firm or not), expenditures financed by the firm itself (this is the sole measure available in the U.S. study), and internal expenditures spent inside the firm (this is the measure we have preferred, since we could obtain it before 1972). We have also the distinction between development, applied and basic research expenditures. Experiments with R&D captial stock constructed from these various measures yielded basically the same results. Further detailed attempts to investigate differences in the efficiency of company financed and public financed R&D or development, applied, and basic R&D did not prove very successful. At best there is some indication of positive composition and interaction effects of the sort found by Mansfield (this volume). Public financed R&D appears to be less productive per se than company-financed R&D, but it appears also to enhance the productivity of the latter significantly. Similarly, basic research, though it may not be as directly productive, interacts positively with applied research and development.

Finally and following the example of the first studies by Terleckyj, we have considered the number of R&D employees as a proxy for the R&D capital stock in the production function. The total estimates are practically unaffected, but the within estimates became much poorer: the estimated $\hat{\gamma}$ is about halved for the scientific firms and is not anymore significant for the other firms.

For details on all these different experiments, the reader is referred to the Cuneo thesis (1982). Table Al indicates our sample composition and size at the two-digit industry level; it gives also the average labor productivity growth rate and the average R&D value-added ratio over our study period 1972-77. Table A2 lists the (geometric) means, (logarithmic) standard deviations, (logarithmic) between and within-firm decomposition of variance, and the average rates of growth of our major variables, separately for the scientific and other firms.

Table A1: Sample Composition and Size, Labor Productivity

Growth Rate, R&D to Value-Added Ratio*

NAP Industry Classification	Number of Firms	Productivity Growth Rate (%)	R&D Value-Added Ratio (%)
Scientific firms			
11 - Chemicals	19	4.2	7.1
12 - Drugs	33	7.2	11.5
15 - Electronic and Electrical Equipment	46	6.6	11.6
Scientific Firms	98	6.4	10.7
Other Firms			
7-8 Primary Metal Industries	8	-.3	2.4
9-10 Stone, Clay and Glass Products	7	3.7	2.6
73 Fabricated Metal Products	8	.0	2.9
14 Machinery and Instruments	26	.6	4.8
16 Automobile and Ground Transportation Equipment	21	1.2	5.3
18 Textiles and Apparel	3	2.7	3.0
21 Paper and Allied Products	6	-.1	1.7
23 Rubber, Miscellaneous Plastic Products	5	-1.3	3.7
Other Firms	84	.8	4.0
All Firms	182	3.8	7.6

*Firm and year average over the study period 1972-77.

Table A2:   Characteristics of Variables*

Main Variables**	Scientific Firms (98)					Other Firms (84)				
	Geometric Mean	Standard Deviation*	Percent Variability Between	Percent Variability Within	Rate of Growth	Geometric Mean	Standard Deviation	Percent Variability Between	Percent Variability Within	Rate of Growth
VA Deflated value added including R-D materials	59.6	1.41	98.2	1.8	7.3	91.2	1.40	98.9	1.1	1.6
L Number of employees excluding R-D employee	0.86	1.38	99.4	0.16	1.0	1.93	1.38	99.6	0.4	0.8
C Gross plant adjusted for inflation and excluding research capital	49.2	1.59	98.9	1.1	7.2	131.2	1.63	99.3	0.7	6.1
K R-D capital stock measure computed using a .15 rate of obsolescence	24.0	1.47	98.8	1.2	6.6	12.4	1.59	98.8	1.2	7.5
S Deflated sales	127.6	1.38	98.9	1.1	5.3	216.6	1.48	99.3	0.7	1.7
M Deflated materials excluding R-D materials	44.0	1.48	98.3	1.7	3.7	92.5	1.66	98.6	1.4	1.6
VA/L Deflated value added per employee	69.4	0.39	80.2	19.8	6.4	47.4	0.25	66.1	33.9	0.8
C/L Gross plant adjusted per employee	57.2	0.70	94.9	5.1	6.2	68.1	0.53	93.7	6.3	5.3
K/L R-D capital stock measure per employee	28.0	0.87	96.5	3.5	5.7	6.4	0.98	96.6	3.4	6.7
S/L Deflated sales per employee	148.5	0.51	95.9	4.1	4.3	112.4	0.38	88.4	11.6	0.9
M/L Deflated materials per employee	51.2	0.72	91.8	8.2	2.7	48.0	0.65	90.1	9.9	0.8

*   Standard deviation and the decomposition of variances are given for the logarithms of the variables.

** All values are in 10^6 francs and constant 1972 prices. The number of employees is in 10^3 persons.
    Rates of growth are yearly averages over 1972-77.

APPENDIX B

R&D Double Counting and the Excess Return Interpretation

In a recently published article (1981), Schankerman pointed out forcefully and analysed explicitly the importance of R&D double counting and expensing in measuring the returns to R&D. Using a large cross-section sample of firms (already investigated by Griliches, 1980), he was able to show that the resulting biases could indeed be quite large. He also made the point that the excess return interpretation, even though it happened to be roughly verified in his particular sample, should be considered as "conceptually incorrect". Using our sample we can provide another striking illustration of the importance of such R&D double counting biases, particularly in the cross-sectional dimension (between or total estimates) and less so in the time dimension (within-firm estimates). We find also that the excess return interpretation is not too far off, at least for our total estimates. If ρ_k and ρ_c are the marginal products or (gross) rates of return to R&D capital and physical capital respectively, we should verify that $\rho_k \sim \hat{\gamma} (V/K) + \rho_c$, or restated in terms of elasticities: $\gamma \sim \hat{\gamma} + \alpha(K/C)$. For the scientific firms, we can take α and γ to be .25 and .20 (total estimates with corrected measures), and $\hat{\gamma}$ to be .10 (total estimate with uncorrected measures), implying that K/C should be around .4, which is about the actual order of magnitude. The same is also roughly true for the other firms.

It is not by mere chance that the excess return interpretion is, in fact, roughly valid, and Schankerman's analysis must be qualified in this respect. It is easy to see intuitively why such interpretation might apply to

a certain degree of approximation. Schankerman's analysis in terms of biases due to omitted corrections, although quite right, tends to obscure the matter. The question is one of functional form, log-linear rather than linear, as much as one of mismeasurement. If we consider only the issue of double counting R&D labor and capital (and ignore that of expensing out R&D materials), and if we assume a linear production function (instead of the Cobb-Douglas function), the excess return interpretation becomes quite intuitive. Assuming a linear formulation we must be more careful about the "units" of measurement of our variables. Define C, L and K as the true service flows of physical capital, labor and R&D capital in value units, and suppose K is made of R&D labor L_r and R&D physical capital C_r i.e. $K = L_r + C_r$, then the true equation and the estimated one are respectively:

$$V = \rho_c C + \rho_\ell L + \rho_k K + e \quad \text{and} \quad V = \rho_c C' + \rho_\ell L' + \rho_k^e K + e \quad , \quad ,$$

where $C' = C + C_r = C(1 + C_r/C)$ and $L' = L + L_r = L(1 + L_r/L)$, and where $\rho_k^e = \rho_k - [(C_r/K)\rho_c + (L_r/K)\rho_\ell]$ is the rate of return of R&D capital in excess of the "normal remuneration" of its labor and physical capital components. One will actually estimate the excess rate of return ρ_k^e, if the variation in (C_r/K) and (L_r/K) is small relative to that of K. This seems reasonable enough across firms of widely different sizes, i.e. in the cross-sectional dimension, for the total estimates. However, for a given firm over time the relative stability of (C_r/C) and (L_r/L) may seem as plausible as that of (C_r/K) and (L_r/K). If this is really so, whether one used the corrected or uncorrected measures of the variables, one would estimate the rate of return ρ_k itself in the time dimension, i.e. for the within-firm estimates.