Volume Title: R & D, Patents, and Productivity

Volume Author/Editor: Zvi Griliches, ed.

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-30884-7

Volume URL: http://www.nber.org/books/gril84-1

Publication Date: 1984

Chapter Title: Productivity and R&D at the Firm Level in French Manufacturing

Chapter Author: Philippe Cuneo, Jacques Mairesse

Chapter URL: http://www.nber.org/chapters/c10059

Chapter pages in book: (p. 375 - 392)

18 Productivity and R & D at the Firm Level in French Manufacturing

Philippe Cuneo and Jacques Mairesse

18.1 Introduction

Following Griliches and Mairesse's study for the United States (this volume), we use a similar analysis to assess whether a significant relationship exists between R & D expenditures and productivity performance at the firm level in French manufacturing. Our purpose is twofold: to check the 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 (Griliches and Mairesse 1983). 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 be-

---

Philippe Cuneo is with the Institut National de la Statistique et des Etudes Economiques. Jacques Mairesse is a professor at Ecole des Hautes Etudes en Sciences Sociales and Ecole de la Statistique et de l'Administration Economique, and a research affiliate of the National Bureau of Economic Research.

The authors are grateful to Zvi Griliches for his interest and advice. Thanks are due also to Alan Siu for his help, and to the Ministry of Industry and Research, and INSEE for providing the various data bases used. Financial support from the Naional Science Foundation (PRA79–13740) and the Centre National de la Recherche Scientifique (ATP–070199) is gratefully acknowledged.

tween 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, because of 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 18.2. We document and discuss the changes in our estimates because of our improved measures of variables in section 18.3. In both sections we systematically refer to Griliches and Mairesse and stress the various comparative aspects of the two studies.

18.2 Framework, Data, and Main Results

18.2.1 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 from 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 on the between-firm ones.

18.2.2 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 Industry and Research (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 restricted to nonmerger firms. The study period, however, is much shorter: 1972–77, compared with 1966–77 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 subtracted 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 subtracted.

Detailed information on the sample and the variables is given in appendix A (see in particular appendix tables 18.A.1 and 18.A.2 which are comparable to the corresponding tables 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 5–10 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.

18.2.3 Main Results

Our main results are presented in table 18.1, again in a format comparable 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 separately.

The total estimates are quite satisfactory on the whole. The elasticity 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.

18.3 Further Results

18.3.1 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. With our data we are able to check whether this makes a real difference. Table 18.2 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 18.1, 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

Table 18.1 **Production Function Estimates for All Firms, and Scientific and Other Firms Separately**

	Total Regressions						Within-Firm Regressions					
	α	γ	$\mu - 1$	λ	R^2	MSE	α	γ	$\mu - 1$	λ	R^2	MSE
All firms	.182	—	—	.019	.105	.1326	.392	—	—	.007	.165	.0219
(182)	(.018)			(.007)			(.042)			(.004)		
	.213	.209	—	.005	.512	.0724	.333	.114	—	.003	.172	.0217
	(.013)	(.007)		(.005)			(.046)	(.035)		(.004)		
	.220	.203	−.018	.005	.516	.0719	.249	.050	−.228	.015	.183	.0215
	(.013)	(.007)	(.006)	(.005)			(.050)	(.039)	(.060)	(.005)		
Scientific	.273	—	—	.039	.287	.1106	.351	—	—	.034	.348	.0201
firms (98)	(.020)			(.008)			(.050)			(.005)		
	.237	.206	—	.030	.489	.0794	.232	.229	—	.029	.372	.0194
	(.017)	(.014)		(.007)			(.055)	(.048)		(.005)		
	.237	.206	−.001	.030	.489	.0794	.152	.144	−.243	.042	.383	.0190
	(.017)	(.014)	(.009)	(.007)			(.060)	(.054)	(.074)	(.006)		
Other firms	.134	—	—	−.008	.086	.0568	.412	—	—	−.023	.071	.0196
(84)	(.020)			(.006)			(.067)			(.005)		
	.175	.116	—	−.019	.288	.0443	.371	.079	—	−.027	.076	.0195
	(.018)	(.010)		(.006)			(.071)	(.047)		(.005)		
	.189	.114	−.018	−.018	.297	.0439	.268	.027	−.245	−.015	.090	.0193
	(.019)	(.010)	(.007)	(.006)			(.080)	(.050)	(.090)	(.007)		

Table 18.2 **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	—	—	—	.015	.293	.1854	.446	—	—	—	.011	.342	.0137
	(.026)				(.011)			(.041)				(.004)		
	.355	.199	—	—	.006	.404	.1565	.341	.200	—	—	.007	.369	.0131
	(.024)	(.019)			(.010)			(.045)	(.040)			(.004)		
	.368	.176	—	−.061	.007	.430	.1501	.181	.028	—	−.491	−.032	.437	.0117
	(.024)	(.019)		(.012)	(.009)			(.047)	(.043)		(.058)	(.005)		
	.123	.143	.535	−.021	.014	.877	.0324	.128	.083	.404	−.160	.021	.710	.0061
	(.012)	(.009)	(.012)	(.006)	(.004)			(.034)	(.031)	(.017)	(.044)	(.003)		
Other firms (84)	.263	—	—	—	−.012	.131	.1257	.341	—	—	—	−.016	.062	.0157
	(.030)				(.009)			(.060)				(.005)		
	.291	.093	—	—	−.019	.187	.1179	.248	.177	—	—	−.022	.096	.0152
	(.030)	(.016)			(.009)			(.063)	(.041)			(.005)		
	.289	.093	—	.002	−.019	.187	.1181	.038	.071	—	−.497	.000	.166	.0140
	(.031)	(.016)		(.012)	(.009)			(.068)	(.043)		(.077)	(.006)		
	.137	.058	.486	−.036	−.006	.797	.0296	.133	.052	.474	−.158	−.005	.682	.0050
	(.016)	(.008)	(.013)	(.006)	(.005)			(.042)	(.027)	(.017)	(.049)	(.004)		

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 practically 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 discrepancies 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 multiplicative factor $1 - \delta$) as well as closer to the total estimates.

Our results confirm that the omission of materials in the sales specification 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 output and materials vary proportionally). It is clear, however, that the sales specifications 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 both of output and labor, and of materials. Griliches and Mairesse have investigated this second possibility by estimating what they call the semireduced form model, and we consider it too.

18.3.2 Semireduced 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 "semireduced form model" expressing the relationship between the endogenous output and labor variables only in terms of the predetermined physical and R & D capital stocks. Using value added and omitting materials (and ignoring also constants, time trends, or year dummies), we get:

$$\begin{aligned} v_{it} &= \alpha' c_{it} + \gamma' k_{it} + e'_{it}, \\ \ell_{it} &= \alpha' c_{it} + \gamma' k_{it} + e''_{it}, \end{aligned} \tag{1}$$

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:

$$
\begin{aligned}
s_{it} &= \alpha' c_{it} + \gamma' k_{it} + e'_{it}, \\
\ell_{it} &= \alpha' c_{it} + \gamma' k_{it} + e''_{it}, \qquad (2) \\
m_{it} &= \alpha' c_{it} + \gamma' k_{it} + e'''_{it},
\end{aligned}
$$

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 semireduced form models using value added or sales are given in table 18.3 for the scientific firms 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 18.1 and 18.2).

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, γ/α ($= \gamma'/\alpha'$), 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 30–40 percent for the scientific firms and 15–20 percent for the other firms. Thus, the absolute size of the within-firm estimates is also a problem for the semireduced form model, and the discrepancy between

Table 18.3 **Semireduced Form Equations Estimates, Scientific and Other Firms Separately**[a]

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

[a] 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 systemwide R^2 given are those of the unconstrained and constrained systems of equations.

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 equivalent to finding decreasing returns to scale for the within-firm estimates of the production function, while finding 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 semireduced form, within-firm estimates are much better looking than the production function, within-firm estimates.

On the whole, the semireduced 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. Other problems 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.

18.3.3 Correcting for the Double Counting of R & D

The Griliches and Mairesse 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 (because of 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 United States. 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 γ of R & D 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 18.4; we also attempt to rationalize them in appendix B.

Following Schankerman (1981), the biases from 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 auxiliary 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 18.4 gives the overall biases and their components

Table 18.4 **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**[a]

		Total Regressions					Within-Firm Regressions				
		α	γ	λ	R^2	MSE	α	γ	λ	R^2	MSE
Scientific	Estimates with	.267	.107	.036	.414	.0743	.217	.170	.035	.362	.0199
firms (98)	uncorrected measures	(.017)	(.014)	(.007)	—	—	(.060)	(.052)	(.005)		
	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	Estimates with	.182	.093	−.018	.240	.0440	.384	.061	−.027	.072	.0197
firms (84)	uncorrected measures	(.018)	(.010)	(.006)			(.072)	(.048)	(.006)		
	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

[a] The estimates of the biases due to R & D materials, capital, and labor are the estimates of the auxiliary 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 18.1). The corresponding R^2 and mean square errors (MSE) are those of the auxiliary 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.

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 firms and other firms, respectively, while the within-firm estimates rise from .17 to .23 and from .06 to .08, respectively. 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, that is, for the scientific firms compared to the other firms and for the R & D labor correction compared to the other two corrections.

18.4 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 United States. 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 the result of better measurement of the variables: (1) we can use a value-added measure of output instead of sales (or equivalently we include materials among the factors of the production function); (2) 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 semireduced form estimates which allow for simultaneity in the determination of output, labor, and 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 that needs to be solved before we shall be able to reconcile our cross-sectional and time-series results completely.

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 aircrafts, boats, and space vehicles industry (ten 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 publicly financed (about 80 percent) contrary to the other R & D intensive industries. The group of other firms in the United States include some nonmanufacturing companies, such as 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 twenty-five "merger firms" (or firms 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 after it is adjusted for inventory changes. Materials are taken simply as total purchases. Computing a proxy for value added as sales minus purchases changed our within estimates slightly. 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 are 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 sixteen 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 French 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 in 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 nine 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 also have the distinction between development, applied, and basic research expenditures. Experiments with R & D capital 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 (1974), 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.

Table 18.A.1 **Sample Composition and Size, Labor Productivity Growth Rate, R & D to Value Added Ratio**[a]

NAP Industry Classification 'Niveau 40'	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
Total 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
13 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
Total other firms	84	.8	4.0
Total all firms	182	3.8	7.6

[a] Firm and year average over the study period 1972–77.

For details on all these different experiments, see Cuneo (1982). Table 18.A.1 indicates our sample composition and size at the two-digit industry level; it also gives the average labor productivity growth rate and the average R & D to value added ratio over our study period, 1972–77. Table 18.A.2 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 18.A.2 **Characteristics of Variables**[a]

		Scientific Firms (98)					Other Firms (84)				
				Percent Variability					Percent Variability		
Main Variables[b]		Geometric Mean	Standard[a] Deviation	Between	Within	Rate of Growth	Geometric Mean	Standard[a] Deviation	Between	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 employees	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

[a] Standard deviation and the decomposition of variances are given for the logarithms of the variables.

[b] 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, Schankerman (1981) pointed out forcefully and analyzed 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 from 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-Doublas 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, that is, $K = L_r + C_r$, then the true equation and the estimated one are, respectively:

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

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, that is, 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, that is, for the within-firm estimates.

References

Cuneo, P. 1982. Recherche developpement et productivité: Une étude économetrique sur donńees de panel. *Thèse de 3ème cycle, Ecole des Hautes Etudes en Sciences Sociales*. Paris.

Griliches, Z. 1979. Issues in assessing the contribution of research and development to productivity growth. *Bell Journal of Economics* 10, no. 1:92–116.

———. 1980. Returns to research and development expenditures in the private sector. In *New developments in productivity measurement and analysis*, ed. J. Kendrick and B. Vaccara, 419–61. Conference on Research in Income and Wealth: Studies in Income and Wealth, vol. 44. Chicago: University of Chicago Press for the National Bureau of Economic Research.

Griliches, Z., and J. Mairesse. 1983. Comparing productivity growth: An exploration of French and U.S. industrial and firm data. *European Economic Review* 21:89–119.

Schankerman, M. 1981. The effects of double-counting and expensing on the measured returns to R & D. *Review of Economics and Statistics* 63, no. 3:454–58.

Terleckyj, N. E. 1974. *Effects of R & D on the productivity growth of industries: An exploratory study*. Washington, D.C.: National Planning Association.