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Chapter Title: Comparing Productivity Growth: An Exploration of French and U.S. Industrial and Firm Data

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7 Comparing Productivity Growth: An Exploration of French and U.S. Industrial and Firm Data

7.1 Introduction

The United States, France, and many other industrial countries experienced a significant slowdown in the growth of productivity in the recent decade. This slowdown exacerbated inflationary pressures and contributed to the growing pessimism about the prospects for future economic growth. Its causes are still unclear and controversial. It makes a difference from a policy response point of view whether it was caused by insufficient investment, by rising energy and raw materials prices, or by a decline in the fecundity of R&D and the exhaustion of technology opportunities.[1]

In this paper we bring a comparative perspective to the analysis of some of these issues. To accomplish this we had to assemble and construct consistent and comparable data sets for French and United States manufacturing industries and firms. After a discussion of the respective data sets and a description of the extent of the slowdown in productivity growth in the two countries and the great variability in it, we turn to an analysis of the potential causes of such fluctuations. At the industrial level, we focus on the contribution of capital

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1. See Denison (1979) and Nordhaus (1982) for a more detailed discussion of some of these issues.

and the rise in material prices to an explanation of the observed productivity slowdown. At the firm level we look also more closely at the potential effect of R&D expenditures on productivity growth. A number of tentative conclusions close the paper.

7.2 Productivity Growth at the Industry Level

7.2.1 Data and Basic Facts

In this section we focus on comparing total factor productivity growth rates in manufacturing industries at the approximate 2-digit level in both France and the United States. Our industry breakdown (described in the appendix table 7A.1) is somewhat unorthodox. It is the result of trying to match the U.S. SIC classification to the French NAP classification, and was chosen primarily on the basis of the availability of the French data, and secondarily because of our interest in R&D (which led us to subdivide several industries). It differs from the usual 2-digit SIC scheme in the U.S. mainly by the separation of drugs and "parachemicals" from the other chemicals, the aggregation of several minor industries, and the exclusion of the petroleum refining industry from manufacturing so defined.

The French estimates are based on national accounts publications, augmented by various unpublished data from the "branch" (establishment level) and "sector" (company level) accounts. The U.S. estimates were aggregated from the 4-digit SIC level detail data base constructed by Fromm et al. (1979) on the basis of the Census Annual Surveys of Manufactures and National Income Accounts based detailed deflators. Both data sets yield a gross output measure (shipments adjusted for inventory changes) in constant (1972) prices and divide inputs into three categories: labor (man-hours), capital (gross capital stock in constant prices), and purchased materials (intermediate consumption including energy inputs). With each input and output measure we associate a set of price indexes and cost shares. For each of our fifteen industries, in both countries, we compute Tornquist Divisia total input indexes and use them to construct Total Factor Productivity (TFP) indexes for the 12-year period, 1967–78, and for two sub-periods, 1967–73 and 1973–78. The final results of these rather extensive computations are given in table 7.1 and illustrated in fig. 7.1.

For the period as a whole, the rate of growth of total factor productivity was higher in France than in the U.S., and this was also true for *each* industry separately. The median difference was on the order of one percent per year with larger differences occurring in the "heavy" industries (Primary Metals, Fabricated Metals, Machinery, and Aircraft and Boats). In both countries productivity growth slowed significantly in the second sub-period, though here the results are much more variable across industries. For aggregate manu-

Table 7.1 **Total Factor Productivity Growth Rates in Manufacturing Industries; France and the United States (percent per year)**

	1967–78			1967–73			1973–78			Change		
Industry	FR	US	FR−US	FR	US	FR−US	FR	US	FR−US	FR	US	FR−US
1. Paper and allied products	1.0	0.8	0.2	0.5	1.8	−1.3	1.5	−0.4	2.0	1.0	−2.3	3.3
2. Chemicals (excluding drugs)	1.5	0.3	1.2	1.8	3.7	−2.0	1.1	−3.7	4.8	−0.7	−7.5	6.8
3. Rubber, misc. plastic products	0.9	0.1	0.8	1.0	1.9	−0.9	0.9	−2.0	2.9	−0.1	−4.0	3.9
4. Stone, clay, and glass products	1.5	0.1	1.4	2.3	1.0	1.4	0.5	−0.9	1.4	−1.9	−1.9	0.0
5. Primary metal industries	1.0	−0.7	1.7	1.7	0.2	1.5	0.2	−1.8	2.0	−1.5	−2.0	0.5
6. Fabricated metal products	1.4	−0.4	1.8	1.9	0.5	1.3	0.7	−1.5	2.3	−1.1	−2.0	0.9
7. Machinery and instruments	1.9	0.1	1.8	3.2	1.1	2.1	0.3	−1.2	1.5	−2.9	−2.3	−0.6
8. Electrical equipment	2.6	1.9	0.7	2.9	1.7	1.2	2.3	2.1	0.2	−0.6	0.3	−0.9
9. Automobile and ground transport	1.8	1.1	0.7	2.6	2.1	0.5	0.9	−0.1	1.0	−1.7	−2.1	0.5
10. Aircraft, boats, and space vehicles	3.4	−0.4	3.7	2.7	−0.9	3.6	4.2	0.3	3.9	1.4	1.2	0.2
11. Textiles and apparel	1.4	0.8	0.6	2.0	0.9	1.1	0.7	0.7	0.0	−1.3	−0.2	−1.2
12. Wood, furniture, and misc. products	1.6	0.1	1.5	2.0	0.9	1.1	1.2	−0.8	2.0	−0.8	−1.7	0.9
13. Printing and publishing	0.6	0.3	0.2	−0.4	0.7	−1.1	1.7	−0.1	1.8	2.1	−0.7	2.8
14. Drugs	0.9	0.9	0.1	1.1	1.4	−0.3	0.7	0.3	0.4	−0.4	−1.1	0.7
15. Leather	1.1	−0.2	1.2	1.9	−0.4	2.3	0.1	0.1	0.0	−1.8	0.5	−2.3
Aggregates												
Aggregate manufacturing	1.7	0.4	1.3	2.2	1.2	1.0	1.2	−0.5	1.7	−0.9	−1.6	0.7
Sectors included in micro study	2.0	0.8	1.2	2.5	1.8	0.7	1.4	−0.5	1.8	−1.2	−2.3	1.1
Sectors not included in mirco study	1.5	0.2	1.3	1.9	0.8	1.1	1.1	−0.5	1.6	−0.8	−1.4	0.6

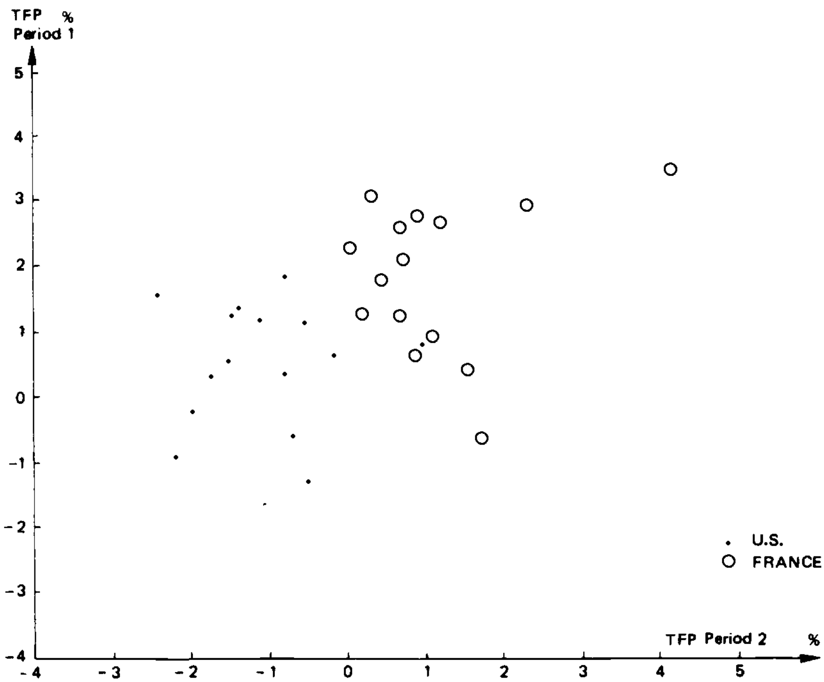

Fig. 7.1 Total factor productivity; fifteen manufacturing industries in France and the U.S., comparison across periods (1: 1967–73, and 2: 1973–78)

facturing the deceleration was somewhat larger in the U.S. (by about 0.7 percent).[2]

If we divide the periods so that they are equal in length and independently constructed, i.e., if we use 1967 to 1972 as our first period, we can do an analysis of variance on the resulting sixty TFP growth numbers, using country, period and industry as classification categories. This yields the following estimates: an average TFP growth rate (in both countries across all industries) of 0.8, an average French advantage over the U.S. of 1.5 percent per year, and an average deceleration of 1.0 percent between the two periods. In terms of contribution to the total variance in TFP growth, the most important factors are country and period, with computed F statistics of 25 and 11, respectively (the 0.05 critical value of the F statistic with 1 and 43 degrees of freedom is about 4). Surprisingly, industrial differences contribute relatively little (the computed $F = 1$ contrasted to a critical $F_{0.95}$ (14,43) of about 2), though individually two industries (electrical equipment and aircraft) have significantly

2. This conclusion depends on the exact choice of time periods. If 1972 is chosen to divide the two time periods instead of 1973, the magnitude of the deceleration is essentially the same in both countries. The U.S. peaked more in 1973.

above average TFP growth rates. This is a rather unfortunate finding from our point of view, since we had hoped to find consistent and significant differences in the rate of productivity growth across industries which might have provided clues to causes of the productivity slowdown. In fact, no consistent industrial differences emerged, either within or across countries.

If we look at the numbers for the more recent sub-period in table 7.1, the biggest difference between the two countries in TFP growth occurs in the chemical (excluding drugs) industry, while the smallest are in textiles, leather, electrical equipment and drugs. It should be noted here that some of these differences may be spurious, the result of errors in the basic data. The biggest potential source of error comes from the price indexes, which could be both erroneous and improperly associated with the relevant industry output. One becomes suspicious of the numbers when one notices that in the U.S. chemical industry capital grew by 5.7 percent per year during 1973–78, materials purchased grew at 9.6 percent, while output went up by only 3.1 percent per year. The other numbers could be wrong, but the suspicion falls on the output number and the associated price index, especially when we note that it had the highest rate of growth of all the industrial price indexes—13.2 percent per year.[3] At this moment, however, we have no way of checking what are basically ingredients of the national income accounts computations. We do want to warn the reader not to place too much confidence in the various numbers; there may still be quite a bit of error left in them.[4]

Looking at table 7.2, which lists the components of the TFP calculation for aggregate manufacturing, we observe that output growth in France was significantly higher in the 1967–73 period (7 vs. 4 percent), and fell by more in the 1973–78 period than in the U.S., to roughly equivalent levels (about 2 percent per year). Throughout both periods, fixed capital was growing faster in France than in the U.S., at the rate of 1 to 2 percent more per year. The big puzzle is in the behavior of man-hours. In the earlier period their growth is small and roughly parallel but diverges sharply during 1973–78. In France labor use declines at about −2 percent per year, while in the U.S. it rises at over 1 percent per year, in the face of a severe output growth slump.[5] There is also a divergence in the materials use story. Materials use is growing much faster in France during the first period and the drop in the second period is much

3. See appendix table 7A.2 for this detail.

4. While there is agreement on the general outlines of the slowdown, there remains much disagreement among various sources about its exact magnitude, especially at the more detailed industrial level. TFP estimates for manufacturing industries at the 2-digit SIC level have been computed in the U.S. by Gollop and Jorgenson (1980) through 1973, and by Kendrick and Grossman (1980) and APC (1981) through 1979. They vary quite a bit from each other (in the 1967–73 overlap period the correlations between these estimates and between them and ours is only on the order of 0.5). Some of the discrepancies could be explained by the use of different data bases (revised vs. unrevised, Census vs. NIPA) and some by differences in methodology (value added vs. gross output, Divisia vs. fixed weight indexes), but the size of some of them remains a puzzle. Within the confines of this paper we cannot pursue this further, but we hope to return to it in the sequel.

5. This difference is smaller if we look at employment rather than man-hours.

Table 7.2 **Growth Rates of Output, Inputs and Prices, and Levels of Factor Shares; French and U.S. Manufacturing Industries, 1967–78**[a]

	1967–78			1967–73			1973–78			Change		
Variable	FR	US	FR−US	FR	US	FR−US	FR	US	FR−US	FR	US	FR−US
Output	4.8	3.2	1.6	7.4	4.1	3.3	1.8	2.1	−0.3	−5.6	−2.0	−3.6
Capital	5.5	3.9	1.6	6.1	4.0	2.1	4.7	3.8	0.9	−1.4	−0.2	−1.2
Employees	0.3	0.4	−0.1	1.5	0.4	1.2	−1.1	0.4	−1.5	−2.6	0.0	−2.6
Man-hours	−0.6	1.0	−1.6	0.8	0.8	0.0	−2.2	1.2	−3.4	−3.0	0.4	3.4
Intermediate consumption	4.5	3.1	1.4	7.4	3.5	3.9	1.2	2.6	−1.4	−6.2	−0.9	−7.1
Price of output	7.1	6.0	1.1	4.6	3.5	1.0	10.2	9.0	1.3	5.6	5.5	0.1
Imputed price of capital	4.9	5.1	−0.2	5.9	4.2	1.7	3.8	6.2	−2.4	−2.1	2.0	−4.1
Price of labor (wage)	13.6	7.2	6.3	10.8	6.2	4.6	17.0	8.5	8.5	6.2	2.3	3.9
Price of interm. cons.	7.4	6.6	0.8	4.9	4.2	0.7	10.5	9.6	0.9	5.6	5.4	0.2
Share of capital in output	0.14	0.23	−0.09	0.15	0.23	−0.09	0.13	0.24	−0.10	−0.02	0.01	−0.03
Share of labor	0.31	0.27	0.05	0.31	0.28	0.03	0.31	0.25	0.06	0.00	−0.03	0.03
Share of interm. cons.	0.54	0.50	0.04	0.54	0.49	0.05	0.55	0.51	0.04	0.01	0.02	−0.01
Labor productivity (man-hours)	5.4	2.2	3.2	6.6	3.3	3.3	4.0	0.9	3.1	−2.6	−2.4	−0.2
Total factor productivity	1.7	0.4	1.3	2.2	1.2	1.0	1.2	−0.5	1.7	−1.0	−1.7	0.7

[a]Growth rates shown are percent per year; factor shares are period geometric averages.

sharper than in the U.S. (from over 7 to about 1 percent per year versus a drop from 3.5 to only 2.5 in the U.S.).

Looking at the price side, average output price inflation was slightly higher in France, by about 1 percent per year, but not strikingly so. This is true also of material prices, which rose slightly faster in France. The big discrepancy, however, is again in labor. Wages appear to have grown much faster in France, accelerating in the second period to a rate *double* that in the U.S. While the real cost of both labor and materials remained roughly constant in the U.S. in the second period (and rose only gradually in the first), in France real labor costs were rising sharply in both periods (at a rate of 6 to 7 percent per year). This may provide a "push" type explanation for the more rapid productivity growth in France than in the U.S. though the causality is far from clear here.[6]

7.2.2 Looking for Causes of the Slowdown: Capital and Materials

There are three potential explanations of the productivity slowdown and the shortfall of the U.S. relative to other countries in this regard which we can explore with our data: differences in investment, a differential rise in materials (and energy) prices, and different R&D policies. Those who claim that part of the productivity slowdown can be explained by a shortfall in the rate of capital investment must have in mind a model in which the contribution of capital to output growth exceeds its factor share for some reason or other (disequilibrium, taxation, or the embodiment of technical change).[7] While capital stock was growing somewhat faster in France than in the U.S., the TFP calculations already take this into account, to a first order of approximation. One way to check on this is to take apart the TFP calculation and ask whether output growth was faster (slower) in sectors which experienced above (below) average growth in capital input.

Define the "production function" as

$$q = \lambda + \alpha l + \beta c + \gamma m + e,$$

where q, l, c, m and λ denote rates of growth of output, labor, capital, materials and disembodied technical change, respectively; α, β, and γ are the respective input elasticies of output, and e is a disturbance term. Approximating the relevant elasticities by their corresponding factor shares, we estimate

$$q = a_{jt} + b_1(s_l l) + b_2(s_c c) + b_3(s_m m) + e,$$

where the constants (technical change terms) are allowed to differ across countries (i) and periods (t). If the TFP calculations are roughly right, the estimated

6. These facts have been noticed before. See, for example, Sachs (1979).

7. They may be thinking primarily of the behavior of output per man-hour, a measure that does not take into account the contribution of the other inputs. Some of the fluctuations in output per man-hour are due to differential movements in capital and/or materials. The concept of total factor productivity attempts to allow for this by including all the major inputs in its definition of total input, weighting them in proportion to their share in total factor costs.

b's should be around unity. If an input is in some sense "more important" than that, it should show up with a coefficient significantly above unity.

The results reported in table 7.3A do not support the capital (or materials) story.[8] Only the labor coefficient exceeds unity significantly and even this result disappears when we exclude the chemical industry with its dubious 1973–78 numbers from the U.S. equation. The capital coefficients are not significantly different from unity, either in the direct production function estimates, or the partial productivity versions, where we first treat labor and then both labor and materials as endogenous variables, constraining their elasticities to equal their factor shares, and subtracting them from the left-hand side.[9] If anything, the coefficient of capital is lower in France than in the U.S., which is exactly the opposite of what would have been needed to provide an explanation for the more rapid productivity growth in France. This is even more obvious when we try to explain cross-country differences in sectoral output growth. There, the estimated capital coefficient actually turns negative, though not significantly so, implying that output was growing faster in France than in the U.S., in industries where the relative capital growth was lower.[10]

As far as materials are concerned, while the direct coefficients are sometimes higher than unity, the differences are not statistically or economically significant. The materials story, suggested especially by Bruno (1981), is based on the notion that in the short-run their elasticity of substitution is less than unity and that a response to a sharp rise in their price is more costly to output growth than is implied by the standard formulae. This can be tested either by looking at the estimated coefficient of materials in the "production function" framework, or by substituting the real price of materials for the more endogenous materials quantity variable.[11]

Treating materials as a separate input with an elasticity of substitution

8. To reduce dependence, these regressions are based on a partition of the data into two non-overlapping periods, 1967–72 and 1973–78. The results are similar when other partitionings, 1967–73 or 1972–78, are used instead.

9. It makes little sense to think of input changes as exogenous in this context of rather aggregate changes over five-year periods. The regressions should be interpreted as a data summary device and not as structural estimates of *the* production function. The partial productivity regressions try to focus on the contribution of specific inputs by constraining the other coefficients to reasonable a priori values.

10. These results are robust to the exclusion of the chemicals industry with its possibly bad U.S. numbers from these regressions and to the use of slightly different time periods.

11. One should note that our definition of purchased materials includes also materials purchased from the same and other manufacturing industries and is not a net "outside" materials concept. The computed materials price changes understate, therefore, the true magnitude of changes in the price of "outside" materials. But the computed share of all "materials" overstates their overall importance, with the product of the two being essentially unaffected by this distinction. Let the computed p_m (rate of growth in materials prices) be $p_m = (1 - d)p_q + dp_0$, where p_q and p_0 are the rates of growth of the industry's own price level and of outside materials prices respectively and d the share of purchases of "outside" materials in total expenditures on materials. Then the variable we use, $s_m(p_m - p_q) = s_m d(p_0 - p_q) = s_0(p_0 - p_q)$, is the same as if we had used the "outside" definition of materials. Our conclusions should, therefore, be robust with respect to the exact definition of "materials" and the boundaries of the various industries. (We are grateful to Michael Bruno for this remark.)

Table 7.3A **Primal Productivity Regressions: Output, Productivity and Price Growth Regressions; Fifteen Manufacturing Industries in the United States and France, 1967–72 and 1973–78[a]**

Dependent variable and country	Coefficients (standard errors) of $s_l l$	$s_c c$	$s_m m$	$[s_m/(1 - s_m)] \times (p_m - p_q)$	Residual standard error
I. *Output, q*					
U.S.	2.21 (0.47)	0.93 (0.43)	0.62 (0.26)		1.21
U.S.[b]	1.13 (0.58)	0.44 (0.58)	1.23 (0.22)		1.20
France	1.36 (0.52)	0.32 (0.54)	1.14 (0.21)		1.18
Combined[b]	1.11 (0.26)	1.08 (1.9)	1.37 (0.16)		1.08
France–U.S.[b]	1.52 (0.60)	−0.43 (0.47)	1.26 (0.29)		1.24
II. *Partial productivity,* $q - s_l l$					
U.S.		0.90 (0.47)	1.11 (0.19)		1.33
France		0.46 (0.50)	1.21 (0.19)		1.17
France − U.S.		−1.15 (0.56)	1.25 (0.17)		1.49
III. *Partial productivity,* $q - s_l l - s_m m$					
U.S.		1.01 (0.42)			1.31
France		0.64 (0.47)			1.17
IV. *Mixed partial productivity,* $q - [s_l/(1 - s_m)]l$					
U.S.		0.92[d] (0.23)		0.64 (0.25)	1.34
France		1.06[d] (0.28)		0.44 (0.14)	1.46
Combined IV[c]		0.87[d] (0.23)		−0.22 (0.32)	n.c.

[a] q, l, c, m and p's are rates of growth of output, labor, capital, materials and of the relevant output and input price indexes $[x = (\log X_t - \log X_{t-5})/5]$.

s_k's are the average (beginning and end period) estimated factor shares of the respective inputs.

Combined equations estimated using generalized least squares, allowing a freely correlated disturbance matrix (4×4) between countries and time periods across industries. I.e., four separate equations (2 periods × 2 countries) are estimated, with the relevant coefficients constrained to be the same across equations.

All equations contain separate unconstrained country and period constant terms.

n.c. stands for not computed.

[b] Excludes the chemicals industry.

[c] Combined IV treats $[s_m/(1 - s_m)](p_m - p_q)$ as endogenous, using $[s_m/(1 - s_m)]p_m$ and $[s_m/(1 - s_m)]p_l$ as additional instrumental variables.

[d] The variable here is $[s_c/(1 - s_m)]c$.

Table 7.3B Dual Price Regressions: Output, Productivity and Price Growth Regressions; Fifteen Manufacturing Industries in the United States and France, 1967–72 and 1973–78

	$s_l p_l$ or $(s_l/s_c)(p_m - p_q)$	$s_c p_c$	$s_m p_m$ or $(s_m/s_c)(p_m - p_q)$	Residual standard error
I. *Output price*, p_q				
U.S.	1.36	0.65	1.67	1.13
	(0.49)	(0.26)	(0.24)	
France	0.96	0.56	0.79	1.20
	(0.28)	(0.57)	(0.19)	
II. *Partial price equation*, $p_q - s_c p_c$*				
U.S.	2.01		1.55	1.09
	(0.34)		(0.19)	
France	0.82		0.79	1.11
	(0.21)		(0.16)	
III. *Factor price frontier*, $p_c - p_q$*				
U.S.	−0.60		0.33	3.99
	(0.69)		(0.54)	
France	0.22		0.04	4.66
	(0.12)		(0.11)	

*Estimated jointly using the SUR procedure.

$\sigma < 1$ between itself and the aggregate of other inputs (value added, consisting of capital and labor) one can write the equation to be estimated as

$$q - \frac{\alpha}{1-\gamma} l = \frac{\lambda}{1-\gamma} + \frac{\beta}{1-\gamma} c - \frac{\gamma\sigma}{1-\gamma} [p_m - p_q] + e,$$

where, in addition to the symbols defined above, p_m and p_q are the growth rates of materials and output prices, respectively.[12] When such an equation is estimated, it yields invariably the wrong sign for the coefficient of the weighted real price of materials $[(s_m/(1 - s_m)](p_m - p_q)$ implying that productivity improved in industries where real material prices rose more rapidly. This could be due to errors in the measurement of industrial output prices, since both the construction of the output variable and the real materials price variable depend on the same output price deflators. An attempt was made to get around this problem by treating $p_m - p_q$ as endogenous and using p_m and p_l (the growth rate of wage rates) as additional instruments. This yielded a negative but not statistically significant coefficient for the real price of materials, with an estimated σ of about 0.2.

Actually, it is not all that surprising that we cannot get much from the materi-

12. See Bruno (1981, eq. 8).

als story since the basic facts go the wrong way.[13] The growth in material use fell more sharply in France than in the U.S. and hence cannot account for the sharper productivity deceleration in the U.S. Nor is there any evidence that real materials prices were rising more rapidly in the U.S. or accelerated more there; if anything, the opposite appears to be the case. Thus, whatever explanation they may provide for the short-term timing of such movements, the rise in material prices cannot explain the persistent and increasing difference between French and U.S. productivity growth.[14]

Another way of looking at the relationships between our variables is to look at the dual price side. Treating output price as dependent, one can write

$$p_q = -\lambda + \alpha p_l + \beta p_c + \gamma p_m + \varepsilon,$$

where, in addition to the terms defined above, p_l and p_c are rates of growth in labor and capital price indexes, and ε is a disturbance. Table 7.3B presents the results of such regressions where, as before, factor shares replace α, β and γ, and the estimated coefficients should be on the order one. Estimates of a "factor price frontier" equation,

$$p_c - p_q = \lambda/\beta - (\alpha/\beta)(p_l - p_q) - \gamma/\beta(p_m - p_q) + \varepsilon,$$

which endogenize the price of capital (using the real return to capital as the dependent variable), are also reported in this table. In the direct price equations there is a stark contrast between the U.S. and France. In the U.S. labor cost and especially material price increases where transmitted to product prices *more* than proportionally, more than could have been predicted by their relative importance in total costs. In France, material price increases appear to have had less than their predicted impact on product prices. When factor price frontier equations are estimated, with the real return to capital as the dependent variable, real material prices invariably come out with the wrong sign. Somehow, the spuriousness introduced by errors in the output price deflators appears to dominate. This is another manifestation of a problem that is endemic to such data—real factor price differences are rather small across industries within any one country, small relative to the size of transitory and erroneously measured movements in output prices.

One way of reducing the endogeneity of the right-hand terms in the factor price frontier equation is to solve out both the output price and the endogenous capital return measure from the right-hand side of this equation. This leads to the estimation of "partial price equations" with $p_q - \beta p_c$ as the dependent variable, i.e.,

13. Moreover, our data are not very powerful in this respect. The real price of materials varies surprisingly little over five-year periods. It appears that most of the materials price changes were passed through to output prices within this length of time.

14. Most of the evidence presented in Bruno (1981) for the materials story is based on aggregate *annual* time series for different countries. France is not considered explicitly and the results for the U.S. are not as good as for some of the other countries.

$$p_q - \beta p_c = \lambda + \alpha p_l + \gamma p_m + \varepsilon .$$

These equations (listed in the middle of table 7.3B) also imply an above average transmission of wage and materials price changes to output prices in the U.S. relative to France. If factor prices have had a special role in this story, it has been their differential impact in the two countries. Thus, they cannot provide a unified explanation for the events in both countries.

7.2.3 The Role of R&D

We cannot really analyze the contribution of R&D to productivity growth in any detail in this section because there are no R&D time series at the industry level in France. We do have, however, French data on R&D expenditures and employment by industry for 1975 and we can use similar U.S. data (see appendix table 7A.3) to investigate whether differences in productivity growth are related to differences in R&D intensity. An earlier study [Griliches and Lichtenberg (1984)] found that one can attribute only very little of the productivity slowdown in the U.S. to the retardation that occurred in the growth of R&D in the late 1960s. This study utilized a more detailed industrial breakdown and showed that the relationship between TFP growth and the R&D to sales ratio did not deteriorate in the 1970s. Moreover, it indicated that the R&D to sales ratios remained relatively stable across industries between the 1960s and 1970s (r^2 for the correlation of R/S in 1964–68 and 1969–73 across twenty-seven manufacturing industries was 0.97). Assuming a similar stability in France, we may use the 1975 data to proxy also for the unavailable earlier data.

If we combine all of our data for the two countries, two periods, and fifteen industries ($N = C \times T \times I = 60$), and estimate a common R&D coefficient in the two countries, using a seemingly unrelated regression framework, we get the following equation:

$$\underset{}{TFP} = \underset{(0.31)}{0.23\ DUS1} - \underset{(0.37)}{1.02\ DUS2} + \underset{(0.31)}{1.49\ DF1} + \underset{(0.29)}{0.76\ DF2} + \underset{(0.09)}{0.28\ R/S},$$

$$SEE = 1.10 ,$$

where *DUS1* is the U.S. constant term (average rate of TFP growth) in the first period, and similarly for the other terms, while *R/S* is the ratio of company financed R&D expenditures to total sales in the respective countries.[15] The estimated R&D coefficient implies a 28 percent excess gross rate of return to R&D investment. It is excess because much of the R&D input is already

15. The OLS estimates, although less precise, are very similar to the SUR estimates. When we use total R&D to sales ratio (or R&D employment to total employment ratio) instead of company R&D to sales ratio, we obtain rather poor and statistically insignificant estimates for the U.S. These are due mainly to one outlier, the U.S. aircraft, boats and space vehicles industry, which had very low TFP growth rates (the lowest in the first period) and the highest total R&D to sales ratio (of which 80 percent is federally funded). When this industry is left out of the sample all estimates

counted once in the construction of labor and capital and it is gross because no allowance has been made for possible depreciation of R&D capital [see Griliches (1979), Schankerman (1981) and Cuneo-Mairesse (1983) for a more detailed interpretation of such coefficients].

When we allow for separate country coefficients we get the following equation instead:

$$TFP = \underset{(0.33)}{0.30}\ DUS1 - \underset{(0.38)}{0.94}\ DUS2 + \underset{(0.36)}{1.42}\ DF1 + \underset{(0.33)}{0.68}\ DF2$$

$$+ \underset{(0.12)}{0.23}\ R/S(US) + \underset{(0.14)}{0.33} R/S(F), \qquad SEE = 1.11.$$

The difference between the U.S. and French coefficient is substantial but not statistically significant.

The estimated *R/S* coefficient for the U.S. (0.23) is comparable to what we found in the earlier study. If we accept such a rate of return or even if it were twice as high, this still would not account for much of the deceleration of TFP in the U.S., since the decline in R&D to sales ratio was in fact rather small.[16] Nor can our estimates account for the differences in TFP growth between France and the U.S., since the R&D to sales ratios tend to be lower at the industry level in France than in the U.S. We shall re-examine this conclusion, however, in the next section where the available micro data contain more information on firm R&D expenditures over a longer time period.

7.3 Productivity Growth at the Firm Level

7.3.1 Data and Basic Facts

In this section we examine the growth of productivity at the firm level. Because of our interest in assessing the contribution of R&D to productivity, we have been assembling data on R&D performing firms in both France and the U.S.[17] Data problems and the desire for comparable and adequately sized samples limited the study period to 1973–1978 and to five manufacturing industries for which we had a sufficient number of firms (at least 30) in each of the countries: Drugs, Chemicals (excluding Drugs), Electronics, Electrical Equipment (excluding Computers), and Machinery. The exact definition of

become comparable. Earlier work has also shown that productivity growth in the U.S. is more closely related to company R&D expenditures than to the federally financed components of total R&D.

16. The total R&D to sales ratio in U.S. manufacturing declines from about 4.4 percent in the mid-1960s to 3.1 in the mid-1970s. The decline is much smaller, however, for company financed R&D, from a peak of 2.2 percent in 1969 to a low of 2.0 in the mid-1970s.

17. See Griliches and Mairesse (1981) and Cuneo and Mairesse (1983) for a description of earlier work and for more detail on these data.

these five industries in terms of the two- or three-digit French NAP or U.S. SIC classifications is indicated in table 7A.4 in the appendix. It differs somewhat from our aggregate industry breakdown. The "parachemical" firms were brought together with the chemical firms (rather than with the drug firms), and the medical instrument firms were added to the "drug" industry. The electronics and electrical equipment firms are treated separately, and computer and (non-medical) instrument firms have been excluded, since there were too few of them in France.

Our samples correspond best to the subtotal of the four aggregate industries (2 + 7 + 8 + 14) given separately in table 7.1 of the previous section. The number of firms is relatively small (N = 185) in the French sample and only somewhat larger (N = 343) in the U.S. one, but these firms do account for about 25 and 85 percent of the total number of employees in these four aggregate industries in France and the U.S., respectively. They are not a representative sample from these industries, however. This occurs, first, because we include only firms which actually perform R&D and, second, because our data cleaning efforts result in additional selection. In particular, firms which grew through major mergers have been excluded.[18]

That the use of similar selection procedures in both countries yields a much lower coverage for the French sample than the U.S. one is rather interesting. Only about a third of the French firms (in terms of the number of employees) in these industries have significant levels of R&D expenditures as against most of the firms in the U.S. This difference in the industrial structure of the two countries also accounts for the observed discrepancy between the R&D to sales ratios at the firm and industry levels in the two countries. (See the data sources appendix for more details.)

In addition to constructing our samples along the same lines for both countries, we also defined and measured our main variables as similarly as possible. Output is defined as deflated sales. The industrial level of the sales deflators depends on their respective availability in the two countries (eleven different price indices for the French and twenty-five for the U.S. data).[19] Labor is measured by the total number of employees and gross physical capital stock by the book value of gross plant adjusted for inflation (based on a rough estimate of the average age of the capital stock). An R&D capital stock variable is constructed as a weighted sum of past R&D expenditures, using a 15 percent rate of depreciation and all of the pre-1973 information on R&D that we could get for our firms.[20] Because materials purchases and labor costs are not separated

18. We recognized "major mergers" by large jumps in the data such as the doubling of gross plant, sales or the number of employees. This eliminated about 50 firms from the French sample and 80 from the U.S. one.

19. For the U.S. sample firm-specific price indices were also computed as weighted averages of sectoral indices, the weights being obtained from the information on sales by different business segments within a company in 1978. Using such firm specific price indices did not alter our results in any significant way.

20. We were able to use R&D data as far back as 1963 for two-thirds of the French sample, and at least back to 1968 for practically all the firms of the French sample and most of the firms in the

for most U.S. firms (they are lumped together in the item "cost of good sold"), it was not possible to treat materials as a separate factor of production and estimate a TFP index similar to that computed at the industry level. We focus, therefore, on labor productivity Q/L and on an approximate TFP measure $Q/[L^{0.75}C^{0.25}]$, which assumes the proportionality of materials to value added and uses constant labor and physical capital cost shares.[21] We also put more emphasis on econometric estimates of the contribution of physical investment and R&D to labor productivity growth, using a standard Cobb-Douglas production function framework to allow factor elasticities to diverge from their corresponding cost shares.

Table 7.4 presents means and standard deviations of the growth rates of our main variables between 1973 and 1978 and of their levels as of 1974. It also reports their weighted growth rates and compares them to the corresponding aggregate growth rates.[22] The standard deviations of the rates of growth of labor productivity are 4.9 and 4.2 percent per year in the French and U.S. samples, respectively, and the corresponding interquartile ranges are [−0.1; 6.0] and [−1.8; 3.4]. In fact, when one looks at any histogram of individual rates of growth, or any plot of them, the scatters overlap widely across countries. This is illustrated in figs. 7.2 and 7.3 which show for both samples the histogram of $q - n$ (labor productivity growth rate) and the plot of $q - n$ against $c - n$ (capital stock per employee growth rate).

Another interesting point is that the dispersion of growth rates, even though quite large in its own terms, is rather small (about a tenth) relative to the dispersion of the corresponding levels. Moreover, growth rates and levels are almost uncorrelated, Gibrat's law of proportionate and independent growth holding also for productivity and not just for the growth in size (number of employees or sales), as it is usually formulated.[23] These two features are reflected in the long period stability of firm rankings by absolute productivity in spite of the great variability in their productivity growth rates.

Looking at the average growth rates of our variables and comparing unweighted to weighted averages, it appears that smaller firms are growing faster than larger ones in the U.S., while no such differential tendency is apparent in

U.S. sample. We tried also alternative measures of R&D capital, retrapolating R&D series on the basis of the corresponding industry growth rates instead of using all the firm information whenever possible and adopting a 30 percent rate of depreciation. The means of such different measures differ of course appreciably (and thus the estimates exhibited in table 7.4 for our main measures are only roughly indicative) but the estimated regression coefficients (elasticities) are practically unchanged.

21. Using specific country and industry cost shares of labor and physical capital (rather than 0.75 and 0.25) to compute an alternative TFP variable did not affect our results significantly.

22. Table 7A.4 in the appendix gives similar detail for the five industry sub-samples.

23. For example, the correlation between the 1973–78 growth in labor productivity and its level in 1974 is only −0.05 and −0.07 in the French and U.S. samples, respectively, while the correlation between the growth rate in employment and its level is only −0.02 and −0.15. Gibrat's "law" asserts that percentage growth rates are independent of both levels and previous growth rates; i.e., the logarithms of levels follow a random walk. See Marris (1979) for references on this and related literature.

Table 7.4 **Characteristics of the Main Variables in the French (N = 185) and U.S. (N = 343) Samples**

	Rates of growth of variables over 1973–78 (except *R/S* for which the 1974 level is given)				Levels of variables in 1974[a]	
	Unweighted sample means (standard deviations)		Weighted sample means [corresponding aggregate estimates]		Unweighted sample means (standard deviations)	
Main variables	FR	US	FR	US	FR	US
Deflated sales per employee, $q - n$	3.2 (4.9)	0.7 (4.2)	3.6 [3.5]	2.2 [1.9]	25.8 (0.4)	33.5 (0.4)
Gross plant adjusted per employee, $c - n$	5.6 (4.9)	5.0 (6.5)	5.5 [6.9]	5.9 [3.3]	9.8 (0.5)	14.6 (0.6)
R&D capital stock per employee, $k - n$	5.9 (6.7)	3.7 (7.9)	5.8	3.6	3.8 (1.0)	3.0 (0.8)
Number of employees, n	0.4 (4.4)	2.5 (7.1)	0.8 [−0.4]	0.8 [1.8]	0.9 (1.3)	3.0 (1.7)
Total factor productivity, *TFP*	1.8 (4.8)	−0.5 (4.1)	2.2 [1.8]	0.8 [1.1]		
R&D to sales ratio in 1971, *R/S*	4.8 (4.4)	2.6 (2.0)	3.7 [2.6]	2.9 [3.0]		

[a]Levels of deflated sales, gross-plant adjusted, R&D capital stock are in millions of dollars. An approximate rate of 5 francs for 1 dollar has been used to convert the French figures. Levels of numbers of employees are in thousand persons. The sample means are the geometric sample means, while the standard deviations are the log-standard deviations.

France. This is particularly striking when we look at the number of employees, but is also true for the growth in sales and capital. Some of this may be explained by differences in the size (and also in the range of sizes) of French and U.S. firms: the geometric means of the number of employees being 900 in France and 3000 in the U.S.[24]

Given all the discrepancies that could have arisen from the selection of our samples and the measurement of our variables, the agreement between our "micro" and "macro" numbers is rather surprising. The weighted sample means and the corresponding four industries aggregates are not that far apart. In France, the growth of R&D firms has been apparently more rapid than that for the corresponding industries as a whole, which is not surprising. Curiously,

24. The arithmetic means of the number of employees are 2,100 and 12,600 in the French and U.S. samples, respectively. While the growth in employment was about the same in France for firms with less than 2,000 employees and for those with more than 2,000 employees, in the U.S. the respective growth rates were 3.6 and 1.7 percent.

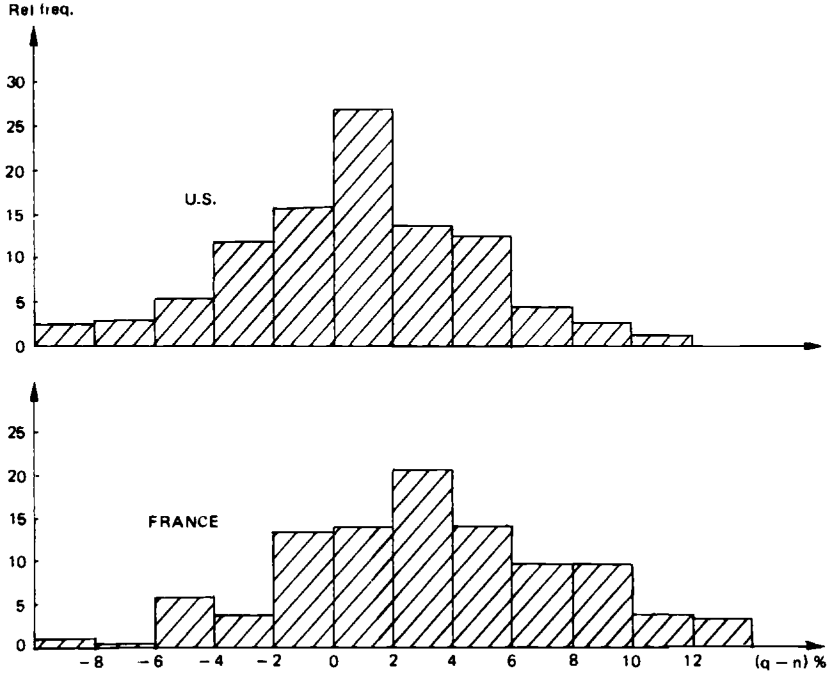

Fig. 7.2 Frequency distributions of labor productivity growth rates; French and U.S. samples, 1973–78

Note: France: Mean = 3.20, standard deviation = 4.85, interquartile range = 6.12. United States: Mean = 0.73, standard deviation = 4.17, interquartile range = 5.20.

the reverse seems to be the case for the U.S., R&D firms having a somewhat lower growth in employment (although they invested more) and a lower growth of sales than the corresponding industries. We have already noted the remarkable difference between our "micro" and "macro" R&D to sales ratios. French firms performing R&D have been investing relatively more in research and development than their U.S. counterparts, but since they constitute a much smaller proportion of the totals the opposite is true for the corresponding industries taken as a whole. The unweighted and weighted average R&D to sales ratios are 4.8 and 3.7 percent, respectively, for the French sample, 2.6 and 2.9 percent for the U.S. sample, while the corresponding industry estimates are 2.6 and 3.0 percent, respectively.[25]

In spite of such differences, a comparison of the 1973–78 productivity growth rates in the two countries yields essentially the same picture as before. Both labor and total factor productivity (based on our rough calculation with

25. The large difference between the unweighted and weighted ratios in France implies a difference in the R&D intensity of small and large firms: 5.1 percent in firms with less than 2,000 employees, 3.8 percent for those with more than 2,000 employees.

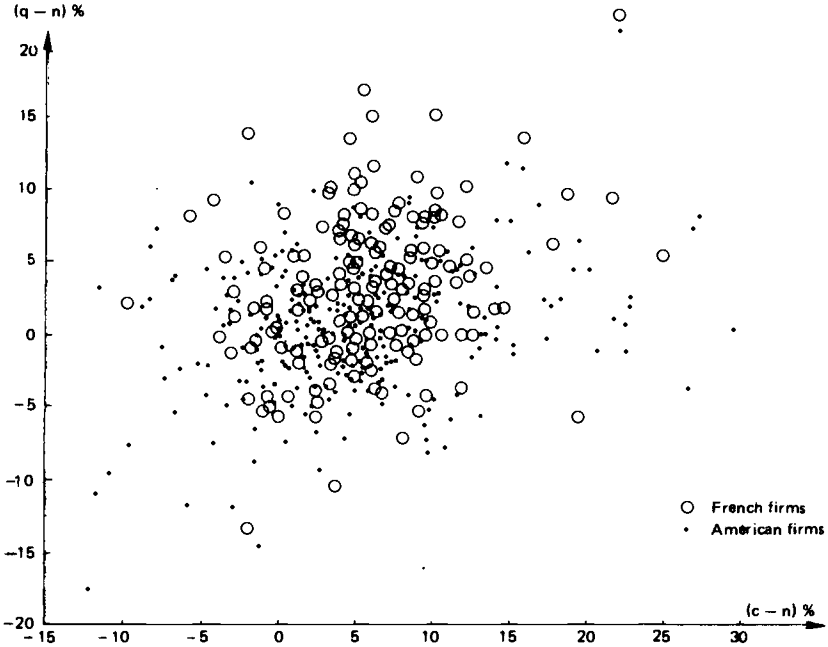

Fig. 7.3 Plot of labor productivity growth rates against the growth in capital-labor ratios; French and U.S. samples, 1973–78

a capital share of 0.25) increased much faster in France than in the U.S., by 1.5 to 2.0 percent per year.

We should, finally, remark on the comparison of productivity levels in the two countries given in table 7.4 using five francs for one dollar as an approximate rate of conversion. Though productivity growth has been more rapid in France, labor productivity levels are still below those in the U.S. by about as much as 25 percent on the average. Part of this gap may be due to differences in physical capital intensity and the scale of enterprises between the two countries.

7.3.2 Assessing the Contribution of R&D to Productivity Growth

In an attempt to assess the contribution of R&D as well as that of physical capital to productivity growth, we find it convenient to pool the French and U.S. samples together. This is not unreasonable since the standard deviations of our variables and the correlations between them are rather similar in both samples. Among different ways of handling such panel data, we chose to analyze differences in firm growth rates between 1973 and 1978. This has the advantage that the general economic situation in these two years was good in both countries, in contrast to the 1975–76 recession years. Compared to using year-to-year growth rates, it also has the advantage of reducing biases due to measurement errors in the variables (diminishing the ratio of error to true variance). In doing so, we discard all the cross-sectional information in our data panel, relying only on its time series components. As we know from the literature on the econometrics of panel data and from previous work, cross-sectional estimates often differ from time series estimates. In our earlier studies [see Griliches-Mairesse (1981) and Cuneo-Mairesse (1983)], they actually provide more sensible estimates of the elasticity of output with respect to R&D capital. Despite that, we do not report here on such cross-sectional estimates to keep the analysis parallel to the first section.

Let us denote by $q - n$, $c - n$ and $k - n$ the annual rate of growth between 1973 and 1978 of labor productivity, physical, and R&D capital–labor ratios respectively (dropping for simplicity the firm subscripts i); and by *COU*, *IND*, *SIZ* the appropriate set of dummy variables indicating whether or not firms belong to one of the two countries, one of the five industries, or one of four size groups (which we defined to control for the different range in the number of employees in the French and U.S. samples). The following types of regressions were estimated:

$$(q - n) = \beta \cdot (c - n) + \delta \cdot (k - n) + DUM + e,$$

or

$$(q - n) = \beta \cdot COU \cdot (c - n) + \delta \cdot COU \cdot (k - n) + DUM + e,$$

or

$$(q - n) = \beta \cdot COU \cdot IND \cdot (c - n) + \delta \cdot COU \cdot IND \cdot (k - n) + DUM + e,$$

where the slope coefficients are first constrained to be constant across countries and industries and then free to differ across countries and also across industries, and where *DUM* denotes either the set of dummy variables *COU*, *IND*, *IND* · *COU*, *SIZ* (thirteen independent ones) or only the sub-set *COU*, *SIZ* (five independent ones). When the full set of dummy variables is included, the regressions are based only on intra-country and intra-industry growth differences. When the industry dummies and their interactions are excluded, the regressions are based also on inter-industry growth differences and are therefore more similar to those computed in section 7.2. To relate these regressions even more closely to the previous analysis and because we did not find evidence of a statistically significant contribution of $k - n$ (the growth in R&D capital) to productivity growth, we used also an R&D intensity variable (*R/S74*) instead of the R&D capital measure. We used the R&D to sales ratio as of 1974 instead of a comparable 1973 ratio, so as to avoid any spurious correlation with the 1973–78 growth rate in labor productivity $q - n$. The substitution of *R/S* for $k - n$ implies a different specification of the production function, one that assumes a constant marginal product for R&D rather than a constant elasticity across firms or industries [see Griliches-Lichtenberg (1984)].

Our main results are summarized in table 7.5 which gives the estimated parameters of interest for a number of specifications we tested. Starting with the simplest analysis of variance which uses only dummy variables, we find that all the effects are statistically significant. Among the various dummy variables, the country and industry effects are most highly significant while the size effects are less so, implying a slight tendency for faster growth of produc-

Table 7.5 **Inter- and Intra-industry Regressions, without and with Industry Dummies (and Possibly Separate Industry Slopes), Respectively: Productivity Growth Differences in Pooled French-U.S. Sample ($N = 185 + 343 = 528$)**

Different specifications	Coefficients (standard errors) of $c - n$	$k - n$	R/S	Residual standard error
France and U.S. combined				
Inter-industry estimates	0.17 (0.04)	0.02 (0.03)		4.26
	0.17 (0.03)		0.28 (0.06)	4.18
Intra-industry estimates	0.16 (0.03)	0.03 (0.03)		3.99
	0.17 (0.03)		0.12 (0.06)	3.99

Different specifications		Coefficients (standard errors) of $(c - n)$ FR	$(c - n)$ US	R/S FR	R/S US	Residual standard error
France and U.S. separately						
Inter-industry estimates		0.19 (0.06)	0.16 (0.04)	0.31 (0.07)	0.19 (0.11)	4.18
Intra-industry estimates, with different industry slopes	Drugs	0.20 (0.09)	0.08 (0.10)	0.27 (0.15)	0.41 (0.23)	
	Chemicals	0.40 (0.19)	0.03 (0.09)	0.00 (0.23)	−0.10 (0.36)	3.99
	Electronics	−0.04 (0.18)	0.21 (0.06)	0.12 (0.11)	−0.06 (0.19)	
	Electrical equipment	0.13 (0.14)	0.15 (0.10)	0.45 (0.24)	−0.44 (0.33)	
	Machinery	0.21 (0.13)	0.25 (0.06)	−0.55 (0.38)	0.11 (0.27)	

tivity in larger firms. The country-industry interactions are just on the border of statistical significance.

In addition to such country and industry effects, physical capital growth also contributes significantly to the growth in labor productivity, especially when constrained to have the same average elasticity in all five industries. The evidence is weaker when different industries are considered separately. But the discrepancies in the estimated elasticities by industries and countries are not statistically significant, and we can maintain the hypothesis of a common elasticity. Given the small size of our industry sub-samples, we cannot really discern differences in elasticities across industries.

In contrast to physical capital, growth in R&D capital is not significant at all, even when we impose a constant elasticity across industries. These negative results may be due to our turbulent sample period [see Griliches-Mairesse (1981)] and also to problems of measurement. Double counting of R&D-related employees and R&D-related capital expenditures in our actual measure of labor and physical capital stock may obscure the relation between productivity and R&D investments. In the French sample, where we can correct for some of these problems, we obtain much more sensible looking estimates, with an estimated output elasticity of R&D capital δ of about 0.1 [see Cuneo-Mairesse (1983)].

On the other hand, the R&D to sales ratio does turn out to contribute significantly to the explanation of the interindustry differences in productivity growth. When it is restricted, however, to the explanation of intra-industry differences, the contribution of *R/S* dwindles to insignificance. In the inter-industry regressions, the estimated coefficient of *R/S* (ρ), which can be interpreted as the marginal product or gross rate of return of R&D, is 0.28, while in the intra-industry regressions (those containing industry dummy variables) it is only 0.12. Part of the discrepancy might be attributable to externalities, the fact that R&D performed by a particular firm may benefit other firms in the same industry. Unfortunately, the evidence of an intra-industry effect becomes especially weak when we relax the constraint that the coefficient ρ be the same in the different industries. Nonetheless, to end on a positive note, it is quite encouraging that the contribution of R&D to productivity growth is confirmed by our analyses at both the industrial and the firm levels. It may even be a bit of luck that the estimated order of magnitude of the overall gross rate of return to investment in R&D comes out so close in both cases: about 0.25, somewhat more perhaps in France and less in the U.S.

7.4 Conclusions

Analyzing the French and U.S. industrial data we confirmed both the fact of faster productivity growth in France and the pervasiveness of the recent productivity slowdown. Looking at the individual industry experiences did not yield any new clues about its sources, but it did reject some old ones. Three explanations of the slowdown were examined and were found not to bear on the differences in productivity growth across the two countries. It has been alleged by some that the productivity slowdown has resulted from insufficient physical investment and this argument has been also used to justify policies that would subsidize savings and investment. The evidence we examined does not indicate any close relationship between investment and the growth in productivity. Industries with above (below) average growth in physical capital did not have an above (below) average growth rate of total factor productivity. The rise in materials and energy prices has also been implicated in the productivity slowdown, working either via a low short-run substitutability of materials for other inputs and/or complementarity between equipment and energy. The evidence we examined at the individual industry level does not support this view. Industries that experienced above average growth in the price of materials, and/or had been more materials-intensive, did not appear to have suffered differentially. The notion that the productivity slowdown is associated with the decline in the growth of R&D expenditures has also been quite prevalent and has led to various proposals (and legislation in the U.S.) to subsidize or provide special tax treatment for R&D. While we did find some modest evidence of a positive effect of R&D on productivity, it could account for only very little of the aggregate cross-country differences, since the overall R&D investment intensities were not higher in France than in the U.S.

Looking at the individual firm data did not change these conclusions. The major impression that emerged was one of variance. At the firm level, the estimated output elasticity of physical capital is positive and statistically significant but does not exceed its factor share in either country. Thus, there is no evidence for the notion that investment in fixed assets is more important in accounting for changes in labor productivity than is already implied in the usual total factor productivity calculations. Because a much smaller proportion of firms in an industry do R&D in France than in the U.S., it turns out that the French sample is more research-intensive than our U.S. one, while the reverse is true at the aggregate level for the corresponding industries. Nevertheless, the estimated R&D effects are statistically significant and of comparable magnitude at both the micro- and macro-level; they cannot account, however, for much of the observed difference in productivity growth.

This is our first look at the comparative performance of manufacturing industries and firms in France and the U.S. It is obvious that we have still many unsolved problems and puzzles, both in the quality of the underlying data and in our understanding the substance of what has happened. But we have made a beginning and hope that others will be encouraged to pursue such comparative studies further.

Appendix
Data Sources at the Industry and the Firm Level

The French industrial data come from the National Accounts data bases. Gross output, materials (intermediate consumption) and their associated price indexes and the total number of employees by industry are taken from "Les comptes de l'industrie" [*Les Collections de l'INSEE* no. C55 (1977), C76 (1979), C92 (1981)]. Hours of work are obtained by multiplying the average total number of employees, over the year, by the average number of hours worked per week by production workers in the same years. The latter is taken from the INSEE national accounts data bank. For a description of the methods used in constructing capital stock, see J. Mairesse, "L'evaluation du capital fixe productif: Methodes et resultats" [*Les Collections de l'INSEE* no. C18–19 (1972)]. The numbers are taken from INSEE national accounts data bank. The share of labor in gross output is computed from the labor share in value added data, available in "Les comptes d'entreprises par secteurs" [see *Les Collections de l'INSEE* no. C78 (1979)] by multiplying them by $(1 - s_m)$, where s_m is the share of materials in gross output. The estimates from the "sectoral" national accounts (based on firms data) are not quite coherent with the other estimates from the "branch" national accounts (more or less based on establishments data). But at our national level of industrial aggregation and for our purpose of computing TFP estimates, the possible discrepancies are negligible.

The U.S. industrial data are aggregated from the 4-digit SIC level data base constructed by the Penn-SRI-Census project [Fromm et al. (1979)] and updated and extended at the NBER by Wayne Gray and Frank Lichtenberg. The basic data come from the Census Annual Surveys of Manufactures, while the price series are based on the underlying detailed national income deflators. Labor input (total hours) is computed by dividing total payrolls in operating establishments by the average hourly wage rate of production workers. It can be interpreted as an estimate of total man-hours in production-worker equivalent units. The capital stock data were constructed by Fawcett and Associates for Penn-SRI by perpetual inventory methods from Census sources. Output and input price indexes are based on unpublished detailed National Income deflators and tabulations. The price index of intermediate consumption was revised at the NBER by using the 1972 I-O table and I-O sector level price indexes constructed by the Bureau of Labor Statistics. The total labor costs were revised at the NBER by adding the payrolls of Central and Auxiliary Offices for Census years and interpolating in the intercensal years.

One source of discrepancies between the French and U.S. industrial data sets is that the latter are based on Census sources and not on NIPA conventions. In particular, in the U.S. Census, the notion of "materials" does not include all intermediate consumption, excluding especially purchased services. Since the capital share (s_c) is computed residually, it is somewhat too high in the U.S.,

Table 7A.1 **France-U.S. Joint Classification of Manufacturing Industries**

Ind.	Niveau 40	Niveau 90 (NAP)	French industries	2–3 digits (SIC)	U.S. industries
1.	T21	50	Papier-Carton	26	Paper and allied products
2.	T11	171, 172, 43	Chimie de base. Fibres synthétiques	28 (less 283, 284, 285, 289)	Chemicals (excluding drugs and pharmaceuticals)
3.	T23	52, 53	Caoutchouc—Matières plastiques	30	Rubber, miscellaneous plastic products
4.	T09, T10	14, 15, 16	Matériaux de construction—Verre	32	Stone, clay and glass products
5.	T07, T08	09, 10, 11, 12, 13	Minerais et métaux ferreux et non-ferreux	33	Primary metal industries
6.	T13	20, 21	Fonderie, travail des métaux	34	Fabricated metal products
7.	T14	22, 23, 24, 25, 34	Construction mécanique	35, 38 (less 357)	Machinery and instruments (excluding computers)
8.	T15A, T15B	27, 28, 291, 292, 30	Matériels électriques et életroniques professionnels et equipement menagers	36, 357	Electrical equipment (including computers)
9.	T16	311, 312	Automobile et transport terrestre	37 (less 372, 373, 376)	Automobile and ground transportation equipment
10.	T17	26, 32, 33	Constructions navales et aéronautique, armenent	372, 373, 376	Aircraft, boats and space vehicles
11.	T18	441, 442, 443, 47	Textile, habillement	22, 23	Textiles and apparel
12.	T20	48, 49	Bois, meubles, industries diverses	24, 25, 39	Wood, furniture and miscellaneous products
13.	T22	51	Presse, imprimerie, édition	27	Printing and publishing
14.	T12	18, 19	Parachimie, pharmacie	283, 284, 285, 289	Drugs and parachemicals
15.	T19	451, 452, 46	Cuir et chaussures	31	Leather

Table 7A.2A Growth Rates of Output and Inputs, and Price of Output[a]

	Q				*C*				*L*				*M*				*PQ*			
	1967–73		1973–78		1967–73		1973–78		1967–73		1973–78		1967–73		1973–78		1967–73		1973–78	
Ind.	FR	US	FR	US	FR	US	FR	US	FR	US	FR	US	FR	US	FR	US	FR	US	FR	US
1.	6.6	4.6	0.9	1.8	6.0	3.7	4.5	3.8	0.7	0.4	−2.9	0.4	8.3	3.3	−0.6	2.3	5.6	3.1	11.8	9.6
2.	10.0	7.3	1.4	3.1	7.3	4.2	1.8	5.7	0.4	0.4	−1.1	2.1	11.8	4.1	0.5	9.6	3.0	0.3	11.8	13.2
3.	9.2	8.8	2.5	2.0	8.2	7.7	3.0	5.6	4.3	4.7	−1.5	3.3	11.0	7.6	3.3	3.6	3.3	2.0	12.4	9.8
4.	7.8	3.7	0.7	1.7	7.6	2.3	4.7	2.5	−0.5	1.5	−3.0	1.0	9.0	3.9	0.8	3.7	5.0	4.7	11.4	9.8
5.	5.1	3.3	0.4	−1.5	4.1	2.7	4.6	1.7	−1.3	0.6	−1.7	−0.8	4.6	4.3	0.1	0.2	6.8	4.6	9.5	11.9
6.	5.2	2.4	−0.2	0.2	6.0	3.9	3.6	3.6	0.7	0.5	−3.0	1.2	4.5	2.0	−0.3	1.1	5.7	4.4	12.1	11.0
7.	8.8	4.5	0.2	2.3	8.5	5.2	7.3	5.2	1.1	1.3	−2.6	3.0	8.2	3.8	−0.3	3.0	4.2	3.5	10.9	9.9
8.	9.6	5.0	6.2	5.3	8.7	6.8	10.2	4.7	3.2	0.6	−0.6	2.0	8.5	3.3	5.1	3.3	2.3	1.8	6.3	5.6
9.	10.3	7.5	3.3	3.0	8.6	3.2	6.9	5.4	4.0	4.2	−0.1	1.3	9.2	6.1	3.0	3.0	4.5	3.3	12.7	8.6
10.	7.9	−4.7	5.9	1.1	2.3	3.2	1.9	0.0	0.3	−6.2	−1.2	0.8	7.7	−4.0	2.5	1.1	3.5	4.0	9.4	9.3
11.	5.1	3.2	−1.9	1.3	2.8	4.2	0.5	2.8	−1.8	0.7	−4.7	−1.2	5.7	2.5	−2.0	0.7	4.5	3.2	9.2	5.3
12.	7.1	4.9	1.6	1.4	5.8	4.1	5.0	4.4	0.5	2.7	−2.2	0.9	7.4	4.6	0.7	1.9	5.5	6.3	8.7	8.4
13.	4.1	2.7	3.0	2.7	6.6	3.1	2.9	1.9	1.4	0.8	−2.0	2.3	6.0	2.4	2.9	3.9	7.4	4.4	10.5	8.3
14.	9.1	5.6	4.1	4.0	8.1	5.3	7.2	3.8	1.6	1.4	0.2	2.2	11.0	4.1	3.8	4.3	2.4	2.2	9.3	7.8
15.	3.1	−2.0	−2.0	−0.2	2.6	1.9	1.7	0.6	−2.0	−2.9	−3.9	−1.2	2.7	−2.4	−1.5	0.0	5.7	5.1	11.9	6.7

[a]*Q*, *C*, *L* and *M* are output, capital stock, labor input (man-hours) and intermediate consumption, respectively. The rates of growth of these (real) quantities and the rate of growth of *PQ*—the price of output—are shown.

Table 7A.2B **Growth Rates of Input Prices and Average Levels of Factor Shares[a]**

	PC				*PL*				*PM*				*SL*				*SM*			
	1967–73		1973–78		1967–73		1973–78		1967–73		1973–78		1967–73		1973–78		1967–73		1973–78	
Ind.	FR	US	FR	US	FR	US	FR	US	FR	US	FR	US	FR	US	FR	US	FR	US	FR	US
1.	3.1	5.0	6.3	5.7	11.3	6.8	21.0	9.3	4.8	4.3	11.9	10.6	0.24	0.24	0.26	0.20	0.61	0.53	0.62	0.56
2.	7.0	4.0	5.2	5.4	12.7	6.6	20.1	9.8	1.0	3.1	12.6	10.9	0.23	0.18	0.25	0.14	0.57	0.48	0.56	0.54
3.	5.0	5.1	5.8	1.5	9.5	5.5	17.8	7.5	0.5	2.3	12.8	11.1	0.34	0.28	0.35	0.26	0.47	0.46	0.50	0.49
4.	3.5	6.7	4.5	8.3	13.3	6.7	15.9	8.3	5.0	4.3	12.5	9.8	0.34	0.30	0.33	0.27	0.44	0.42	0.47	0.45
5.	9.7	3.3	−5.5	6.1	12.5	7.1	16.4	10.4	7.3	4.5	10.1	11.0	0.20	0.24	0.21	0.22	0.67	0.60	0.68	0.62
6.	5.4	4.1	5.9	6.8	12.0	6.2	17.5	8.2	5.1	4.6	10.9	11.3	0.38	0.31	0.42	0.28	0.46	0.48	0.43	0.49
7.	2.6	3.5	0.7	6.2	10.0	6.1	16.5	8.2	7.5	4.2	10.6	10.4	0.39	0.32	0.39	0.30	0.44	0.42	0.46	0.43
8.	4.0	1.6	−1.8	6.9	8.8	5.7	13.9	8.1	3.0	3.1	8.7	7.8	0.37	0.32	0.36	0.31	0.45	0.43	0.48	0.44
9.	9.2	8.2	7.6	3.4	12.4	7.1	19.7	9.6	4.3	4.3	11.7	9.5	0.29	0.18	0.31	0.18	0.59	0.65	0.56	0.67
10.	1.4	−6.5	18.9	12.5	8.4	6.5	21.0	8.3	6.1	4.1	10.8	9.7	0.29	0.41	0.28	0.39	0.63	0.41	0.64	0.42
11.	8.5	3.9	2.9	3.4	10.2	5.5	15.0	7.6	4.3	3.5	8.7	6.2	0.31	0.26	0.31	0.25	0.57	0.55	0.59	0.56
12.	6.4	9.3	2.5	3.8	10.0	6.4	14.4	8.1	6.4	6.8	9.5	9.0	0.31	0.28	0.29	0.26	0.55	0.50	0.59	0.52
13.	4.5	4.6	7.6	9.4	10.0	6.4	15.6	6.6	5.7	4.2	11.5	8.7	0.33	0.36	0.33	0.34	0.55	0.33	0.56	0.35
14.	−0.7	2.5	4.1	6.4	7.0	6.6	13.2	8.1	3.0	3.6	10.2	10.0	0.27	0.17	0.22	0.16	0.57	0.38	0.66	0.42
15.	6.8	1.3	9.9	6.0	11.0	5.2	18.9	6.9	6.0	5.8	8.0	7.1	0.31	0.31	0.36	0.29	0.58	0.48	0.52	0.50

[a]*PC, PL* and *PM* are the price of capital (imputed), labor (the wage rate) and intermediate consumption, respectively. The rates of growth of these prices and the average levels of *SL* and *SM*—the shares of *L* and *M* in output—are shown.

Table 7A.3 **Various Measures of R&D Intensity[a]**

	R&D percent of sales					
	Total R&D		Company R&D		R&D employees per 1,000	
Ind.	FR	US	FR	US	FR	US
1.	0.1	0.6	0.1	0.6	0.3	0.8
2.	2.9	3.5	2.7	2.9	5.4	3.5
3.	2.0	1.7	2.0	1.1	2.5	1.4
4.	0.6	0.8	0.6	0.8	0.6	0.7
5.	0.5	0.5	0.5	0.5	1.0	0.6
6.	0.2	0.4	0.2	0.4	0.3	0.5
7.	0.8	2.0	0.8	1.2	1.0	1.0
8.	6.4	7.7	3.5	4.9	6.7	4.9
9.	2.2	3.2	2.2	2.7	2.9	2.5
10.	8.0	12.7	4.4	2.8	9.9	7.2
11.	0.1	0.1	0.1	0.1	0.0	0.1
12.	0.0	0.3	0.0	0.3	0.0	0.3
13.	0.0	0.2	0.0	0.2	0.0	0.2
14.	3.1	3.7	3.2	3.7	6.2	4.5
15.	0.0	0.1	0.0	0.1	0.0	0.0

[a]French R&D numbers are estimated from "Le compte satellite de le recherche, Methodes et series 1970–1976," *Les Collections de l'INSEE* C85 (1979), and U.S. ones are estimated from NSF79.313, *Research and Development in Industries, Detailed Statistical Tables* (1979).

perhaps by as much as a third (see the attempt at reconciliation of value added and GNP originating in the *U.S. Census of Manufacturers,* 1977, Vol. 1, p. XXVII).

The French firm sample is the result of matching two different data sources: INSEE provided us with the balance-sheet and current account numbers (from the SUSE files) while the Ministry of Research and Industry provided the R&D numbers (from the annual survey on company R&D expenditures). The U.S. firm sample is built from the information available in the Standard and Poor's Compustat Industrial Tape. These samples are larger than the ones actually used in Griliches-Mairesse (1981) and Cuneo-Mairesse (1983). More details on the construction and cleaning of the samples, as well as on the definition and measurement of the variables can be found in these two studies.

Table 7A.4 **1973–78 Rates of Growth of the Main Variables by Industry in the French and U.S. Firm Samples (1974 Levels for *R/S*); Unweighted Means with Standard Deviations Given in Parentheses**

	Drugs		Chemicals		Electronics		Electrical equipment		Machinery	
FR: Niveau + 90−600 (NAP)	19 + 1811		17 + 18		291		28 + 292 + 30		22 thru 25 + 3407	
US: 3–4 digits (SIC)	283 + 2844+ 3841 + 3843		28 (−283 − 2844)		366 + 367		36 (−366 − 367)		35 (−357)	
Country	FR	US	FR	US	FR	US	FR	US	FR	US
Subsample size	47	57	30	62	37	65	32	47	39	112
Deflated sales per employee, $q - n$	4.5	0.1	2.2	1.1	5.4	3.0	3.2	0.1	0.3	−0.5
	(4.8)	(3.7)	(5.0)	(3.5)	(4.7)	(4.7)	(4.3)	(4.0)	(3.9)	(4.0)
Gross plant adjusted per employee, $c - n$	5.7	3.8	5.6	5.7	6.0	4.3	5.1	5.6	5.3	5.3
	(6.2)	(5.8)	(3.7)	(5.8)	(3.6)	(8.2)	(5.0)	(6.0)	(4.9)	(6.2)
Total factor productivity, *TFP*	3.0	−0.1	0.8	−0.3	3.9	1.9	2.0	−0.1	−1.0	−1.8
	(4.7)	(3.7)	(4.8)	(3.7)	(4.7)	(4.4)	(4.3)	(4.0)	(3.7)	(3.6)
R&D capital stock per employee, $k - n$	6.5	3.1	4.4	3.5	6.1	3.0	5.0	4.9	6.9	4.1
	(6.5)	(7.1)	(5.5)	(7.2)	(6.2)	(7.8)	(6.0)	(6.9)	(8.4)	(9.1)
Number of employees, n	0.2	5.5	0.5	1.2	1.8	3.4	0.6	−0.0	−1.1	2.4
	(4.4)	(7.2)	(3.5)	(5.9)	(4.5)	(8.2)	(4.6)	(6.7)	(4.5)	(6.5)
R&D to sales ratio in 1974, *R/S*	6.4	3.4	3.6	2.6	7.8	3.5	3.2	2.0	2.0	1.9
	(3.9)	(2.4)	(3.3)	(1.5)	(6.0)	(2.6)	(3.0)	(1.8)	(1.7)	(1.4)

Table 7A.5 ***Sample Comparisons:*** **Numbers of Employees (E) in Thousands and R&D to Sales Ratios (R/S) in Percent, for the French and U.S. Samples, for the Corresponding Aggregate Industries, and Also for All "R&D-Doing Firms" in the Two Countries[a]**

	Samples (S)		R&D doing firms (R)		Corresponding industries (I)			Coverage	
	E_S	$(R/S)_S$ (%)	E_R	$(R/S)_R$ (%)	E_I	$(R/S)_I$ (%)	$(RT/S)_I$ (%)	E_S/E_I (%)	E_R/E_S (%)
France (1974)	395	3.7	565	4.3	1,550	2.6	3.3	25	35
U.S. (1976)	4,250	2.9	4,500	2.6	4,900	2.9	4.1	85	90

[a]The estimates for the samples and the corresponding industries are the ones obtained in this study. The estimates for the "R&D doing firms" are computed from "La recherche-developpement dans les entreprises industrielles en 1974" [*Documentation Française,* 1977] and from "Who does R&D and who patents?" [Bound et al. (1984)]. RT/S refers to the ratio of total R&D performed in the industry (whether company or public financed), while R/S refers only to company-financed R&D. These estimates are only indicative and can be misleading for a number of reasons. First, they are not strictly comparable, since computers and non-medical instruments are not included in our samples, while they are part of the corresponding industries. This explains specifically why $(R/S)_I$ appears to be higher than $(R/S)_S$ and $(R/S)_R$ in the U.S. Second, they are not strictly comparable also due to the conglomerateness and the importance of foreign activities of many of our firms, particularly in the U.S., while the industry level numbers are establishment-based and cover only domestic activities. This results in a severe overestimation of the coverage ratios in the U.S., but is not enough to change the finding that the proportion of R&D doing firms in the industries considered is much less in France than in the U.S. Third, the cutoff point between R&D and non-R&D doing firms seems somewhat higher in France than in the U.S. This is not enough, however, to account for the finding that R&D doing firms appear to do relatively more R&D in proportion to their sales in France than in the U.S. Fourth, the picture differs across industries, the coverage and the R&D sales ratios being both much less for machinery than for drugs and chemicals or for electronics and electrical equipment.

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