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**The Time Series Relationship Between Investment
and Cash Flow in the Scientific Sector:
A Panel Data Study Comparing French, Japanese,
and the United States Firms**

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July 1995

Key words: R&D, investment, cash flow

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Abstract

In a recent paper, Mairesse and Hall (1994) found evidence that investment in both research and development and in physical capital were more sensitive to sales growth in the United States than in France, suggesting that either demand shocks or liquidity constraints play a more important role in determining investment in the former country than in the latter. If true, this is an important finding that is relevant to the current debate in the economic policy literature on the role of financial institutions and corporate governance in the conduct of industrial policy (broadly defined). For example, some have argued that U.S. financial institutions force firms to have the kind of short-term investment horizons that might lead to excess sensitivity of investment to current income, contrasting the U.S. institutional framework unfavorably with those of Japan and parts of Western Europe. This paper makes two contributions to the debate: first, it adds evidence from a panel of Japanese firms to the results from the prior Mairesse and Hall study. Second, it investigates this finding in a more systematic way using the Vector Auto Regressive (VAR) methodology to test for causal relationship among our key variables, output, employment, R&D, investment, and profits. We perform this testing using three large panels of firms in the scientific (high technology) sectors, one for each country.

Preliminary findings are that both investment and R&D are more highly sensitive to cash flow (and sales) in the United States than in France and Japan, although investment in Japan exhibits some sensitivity. Correspondingly, both investment and R&D predict both cash flow and sales positively in the United States, while the impact is somewhat more mixed in the other countries, with only R&D exhibiting uniformly positive predictive effects.

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**THE TIME SERIES RELATIONSHIP BETWEEN INVESTMENT AND CASH FLOW
IN THE SCIENTIFIC SECTOR: A PANEL DATA STUDY COMPARING
FRENCH, JAPANESE, AND UNITED STATES FIRMS**

Lee Branstetter, Bruno Crepon, Bronwyn H. Hall, and Jacques Mairesse¹

I. Introduction

It is a widely held view that the capital market and corporate governance systems of such countries as France, Germany, and Japan differ in important ways from those of the so-called "Anglo-Saxon" countries, the United States, the United Kingdom, and possibly Canada. Those who hold this view argue that features such as interlocking directorates, large scale share-holding by banks, restrictions on and the absence of hostile takeover activity, relatively less active share markets, and a general tendency to rely on voice rather than exit lead to more extensive monitoring by large institutional shareholders and possibly to a greater willingness on the part of firms to undertake long term risky investments than exists in the more actively traded capital markets of the United States and the United Kingdom.²

If this view is accurate, it is natural to ask whether one can see its effects in the investment patterns of firms in these countries, and in their relationship to such indicators of financial performance as sales and cash flow. We think that looking at the

¹Harvard University and NBER; INSEE and visiting NBER; UC Berkeley and NBER, visiting Nuffield College, Oxford University; INSEE/CREST, EHESS, and NBER.

²Among others, see Franks and Mayer (1990) [France, Germany, and the U.K.], Kester (1992) [Japan and Germany], Mayer and Alexander (1990) [Germany and UK], and Hoshi, Kashyap, and Scharfstein (1990) [Japan], Hall (1994) [U.S. plus some international comparisons], and Soskice (1995) [Germany, Japan, U.S., U.K., and France] for evidence on this topic.

dynamic relationships of output measures such as deflated sales and cash flow with investment inputs (both tangible and intangible) in similar samples of firms in a comparison group of countries is one way to investigate whether the institutional difference in these countries, which undoubtedly exist, have consequences for the real behavior of firms. If we cannot see evidence of differences at this level, then it seems unlikely that the contrasting institutional features can be having much of an impact on the firms' actual performance.

In Hall and Mairesse (1995), two of us found evidence that investment in both research and development and in physical capital were more sensitive to sales growth in the United States than in France, suggesting that either demand shocks or liquidity constraints play a more important role in determining investment in the former country than the latter. In work closely related to ours, Bond, Elston, Mairesse, and Mulkey (1994) found that UK investment was more sensitive to cash flow or profits than investment in France, Germany, or Belgium; this finding was robust to changes in specification of the investment equation, although they did not consider research and development investment.

The current paper extends our earlier work by adding cash flow directly as a variable, and by augmenting the data samples with data on another country whose institutions differ from both those in the United States and France, that is, Japan. For data reasons, and because we are particularly interested in the role played by country environments in the encouragement of industrial innovation and technical change, we restrict our sample in this paper to firms in the scientific or high technology sectors in these countries., that is, Chemicals, Pharmaceuticals, Electrical Machinery, Computing Equipment, Electronics, and Scientific Instruments.³

³We have excluded aircraft and aerospace because of the large share of federal government spending on investment in these industries, and the role of the federal government as the

Our second motivation in undertaking this study is an interest in exploring further the use of efficient Generalized Method of Moments estimation on panel data where we allow for the presence of both correlated effects and lagged dependent variables. In this, our immediate inspiration was Holtz-Eakin, Newey, and Rosen (1988), although we have also made use of ideas in Arellano and Bond (1991), and Blundell and Bond (1995). An appendix to this paper chronicles some of our simulation experience with the problem of distinguishing a model with correlated effects from one in which there are no effects, but where each firm's data follows an autoregressive process with a unit root in short panels. Our conclusions are twofold: First, we find that it is frequently difficult to distinguish the two when the lag length is unknown. Second, instrumental variable estimation (GMM) of models with correlated effects is subject to substantial finite sample bias even in fairly good-sized sample sizes (approximately 300-400 firms), when the number of time periods available is fairly large (12 years, in our case) and the efficient estimator is used.⁴ Because of this, we use a slightly less efficient estimator in the body of the paper (fewer instruments) that is somewhat better behaved.

The current version of the paper has the following structure: first, we describe our datasets, and how we attempt to make them as comparable as we can across the three countries. We present some basic descriptive data in order to illustrate the similarities and differences. This is followed by a section where we explore the question of whether the univariate time series properties of our basic variable set (deflated sales, R&D investment,

primary customer for the output, which means that these industries behave quite differently in these three countries, for reasons largely unrelated to our central interest.

⁴In the case here, where we have lagged predetermined variables as regressors (not strictly exogenous) and fixed firm effects, the number of orthogonality conditions in the efficient GMM estimator increases at the rate T^2 in general.

ordinary investment, number of employees, and cash flow before investment and taxes) suggest the presence of correlated firm effects. This comes down to a question of whether the same autoregressive process can be used to describe the series in levels and in differences. Our conclusion here is that firm effects are required for most series, with the exception of labor in France and Japan, and sales in France. We therefore include permanent firm effects in all the models in the subsequent section.

This next section contains the meat of the paper: the results of bivariate causality testing between our two output measures (deflated sales and cash flow) and our two investment measures (R&D and ordinary investment). In a future version, we plan to expand the bivariate model to control for other variables, but we believe that the current results are worth reporting even in the absence of such controls.

II. Data and Descriptive Statistics

Our goal is to produce similar samples of high-technology manufacturing firms for each of our countries: France, the United States, and Japan. However, our sources of data are quite different and this means that the samples will never be exactly comparable, although they are quite representative. Table 1 gives the sources of our data, our deflators, and some indication of the number of observations available to us, both before and after cleaning. The primary difference in the data sources is between France and the other two countries: in France, we have access to a Census of Manufactures-type sample with R&D data collected in survey form by the government for the *Ministere de la Recherche*. This means the data tend to be at a level somewhat lower than that of consolidated accounts (the "group" level), and that it is not confined to publicly traded firms.⁵ For the other two countries,

⁵In this, our problem is similar to that of Bond et al (1994), who had consolidated data for the UK and not for France, Germany, and Belgium. However, there is an important difference

we have data based on the filings of publicly-traded firms with agencies charged with monitoring the financial markets. In the case of Japan, the R&D data has been augmented with data from another survey, because the quality of publicly reported R&D data is very uneven.⁶ Although the Japanese accounts are unconsolidated in the sense that they are not at the "group" level, they are consolidated to a level roughly comparable to that in the United States.

The deflators also differ somewhat across countries, although we hope to improve on this in the future. In all cases, we deflate R&D, investment, and cash flow by a deflator that is common across all industries (on the argument that the factor markets for these industries ought to be in some kind of equilibrium, that is, that the same investment goods may be used on more than one industry). On the other hand, we have attempted to varying degrees to construct real output measures rather than sales by deflating our sales figures by at least a 2-digit-level deflator. In the United States, we are using deflators aggregated up to the 2-digit level from the NBER Productivity Database, which is at the 4-digit level (Bartelsman and Gray 1994).⁷ In France, we are simply using the N40 industry level deflator (approximately 2-digit); these deflators do not contain very much of the type of hedonic quality adjustment that is used in the United States. In Japan, we have

here, in that our Japanese data is also consolidated, even though these data come from a corporate capital system that is closer to that of Germany (or even France) than the US or UK. We believe this provides a useful check on the importance of such considerations in producing our results.

⁶See Griliches and Mairesse (1990) for further discussion of this point.

⁷In this version of the paper, we have not yet incorporated the 2-digit deflation; because of the large impact this has on numbers in the computing equipment sector, we intend in the future to produce estimates for both deflated and undeflated sales in order to examine the differential behavior of sales and output.

constructed "firm-level" deflators based on the 4-digit industry composition of the firm's output. As indicated above, future versions of this paper will examine the contrast between these output measures and the pure sales measure.

Our choice of years (1978-1989) reflects data availability, as well as a desire to have a fairly long time series available for each variable for use in instrumental variables estimation. Because these datasets are large, and in some cases fairly dirty, and because we want to focus on the common time series properties across firms, rather than isolated reorganizations and other specific disturbances, we apply cleaning rules to all the variables: First, we require their growth rates to be between -90% and 900%. Second, in order to remove erroneous data values that might produce misleading autoregressive estimates, we remove firms that have sequential growth rates that are large and alternate in sign. For sales and employment, large is defined as below -50% or above 100%; for R&D, it is -67%, 200%; for investment and cash flow, it is -80%, 400%.

After cleaning, and requiring a full 12 years of data for each firm, we are left with 204 firms for the United States, 156 for France, and 221 for Japan. Table 2 gives some indication of the typical size of these firms, and their importance in their national economies. Each sample is a small but not insignificant portion of its economy, and a larger fraction of that economy's private R&D activity. The Japanese sample has the largest share and the French sample the smallest. Although the national R&D intensities are ranked Japan (2.2%), the U.S. (2.0%), and France (1.6%), the typical firm in these samples is more R&D-intensive in the U.S. (with an R&D to sales ratio of 4.0%) , followed by France (3.6%) , and then Japan (2.8%). This perhaps reflects the somewhat greater selectivity of the U.S. and French samples, and the large integrated firm structure typical of Japan. Because of this vertical integration, we suspect that our Japanese firms are slightly less concentrated in

the high-technology sector than the sample of firms from the other two countries.

TABLE 1
DATASET CHARACTERISTICS

	FRANCE	UNITED STATES	JAPAN
Source	Enquete annuelle sur les moyens consacres a la recherche et au developpement dans les entreprises; Enquete annuelle des entreprises	Standard and Poor's Compustat Data - annual industrial and OTC, based on 10-K filings to SEC	Needs data; data from JDB (R&D data from Toyo Keizai survey)
Deflators	N40 (2-digit)	NBER Productivity database (B&G), agg. to 2-digit level	GDP deflators (firm level)
Scientific Sector⁸	1978-89, good R&D	1978-89, good R&D	1978-89, good R&D
# firms	953	863	424
# observations	5,842	6,417	5,088
Cleaned (#obs.)	5,139	5,721	4,260
No jumps (#obs.)	5,108	5,312	4,215
Balanced 1978-89	1,872 (156 firms)	2,448 (204 firms)	2,652 (221 firms)
Positive Cash Flow	104 firms	174 firms	200 firms

⁸This sector consists of firms in Chemicals, Pharmaceuticals, Electrical Machinery, Computing Equipment, Electronics, and Scientific Instruments.

TABLE 2
SAMPLE COMPARISON
The Median Firm (National Currency)

Variable	United States (\$M 1987)	France (M FF 1987)	Japan (100M yen 1987)
Sales	249.0	465.6	570.6
R&D	9.8	16.2	15.1
Investment	14.0	15.3	42.4
Cash Flow	43.9	59.7	62.1
Employment (numbers)	2,762	604	1,732

The Median Firm (at PPP Exchange Rates in \$M 1987)

Variable	United States	France	Japan
Sales	249.0	67.3	283.5
R&D	9.8	2.4	7.5
Investment	14.0	2.1	21.1
Cash Flow	43.9	8.4	30.9
1989 GDP (\$B87) ⁹	4,730.	758.	1,885.
Sample Sales/GDP	10.1%	5.4%	17.1%
1989 BERD (\$B87) ¹⁰	93.9	12.0	40.9
Sample share of BERD	29.9%	21.0%	41.2%

⁹GDP in 1989\$ at PPP exchange rates is from OECD (1991a), converted to 1987\$.

¹⁰BERD is Business Enterprise R&D, from OECD (1991b) in 1989\$ at PPP exchange rates, converted to 1987\$.

Figures 1 and 2 display the trends in the median growth rates and interquartile ranges for the three samples. The first thing to note in these figures is that there is more difference in the patterns among the variables than among the countries, with cash flow and ordinary investment fluctuating much more over the cycle than sales, R&D, and employment. The dispersion of growth rates in all 3 countries is also quite similar across the variables, except for the rather anomalous cash flow range in France. It is perhaps worth noting also that the fluctuations of the median and interquartile dispersion of employment growth rates is somewhat higher in the United States, although relatively low in all 3 countries. In other words, over the business cycle firms tend to increase and decrease employment more in the United States than in Japan and France, and the dispersion in this behavior is higher.

Figure 3 shows the trends in three ratios over the three countries: the median R&D intensity, the median investment to sales ratio, and the median cash flow to sales ratio. It is noteworthy that the R&D to sales ratio is flat in France, while it increases during the period in both the U.S. and Japan. The Japanese capital expenditure rate is higher than the U.S. and the French rate lower throughout the 1980s. By the end of the period, both the U.S. and France have R&D intensities for these samples of firms that are within one percentage point of the investment to sales ratio, while Japan's is still somewhat lower (just over 3 percent for R&D as compared with 7 percent for capital expenditures).¹¹ Finally, the trends in cash flow seem also to differ across countries: constant in the United States, increasing in France, and falling in Japan. This cash flow measure is supposed to be approximately equal to revenues less labor and material costs in all three countries: that is, it is supposed to be a measure of cash available for both kinds of investment, as well as for

¹¹Again, we believe this may reflect the level of vertical integration in these firms.

payments to shareholders, possibly bondholders, and the government. However, accounting conventions differ from country to country, and it is not clear at this point whether interest and taxes have been included in this variable in some cases. Even with this caveat, it is perhaps interesting to note that cash flow net of these two investment streams is approximately zero for Japan, while it is still quite positive and of roughly the same order of magnitude for France and the United States.

As a final summary of the data relationships in our three samples, we present the simple correlations of the growth rates of our five key variables in Table 3. With the exception of the correlation of R&D growth and cash flow growth (which may be related to the way the data was constructed), in all cases the correlations are highest for the United States.

TABLE 3
CORRELATION OF DEFLATED GROWTH RATES: 1978-1989

	Sales	R&D	Investment	Employment
R&D	.324, .138, .208			
Investment	.314, .231, .258	.181, .146, .095		
Employment	.609, .551, .197	.271, .170, .118	.376, .262, .172	
Cash Flow	.561, .142, .531	.130, .100, .212	.165, .061, .166	.294, .059, .048

The correlations shown are ordered U.S., France, Japan. The number of firms is 204, 256, and 221 respectively, except for the cash flow correlations, where the numbers are 174, 104, and 200.

From this preliminary survey of the sample characteristics, it is possible to conclude

that there are no real surprises in the data: as expected, the United States generally exhibits higher correlations of most variables with cash flow, and United States employment fluctuates more over the cycle. In addition, Japanese investment is generally quite high, and there does seem to be a tendency to invest at a much higher rate out of profits in Japan. However, there still exist some puzzles in the cash flow data, and also some evidence that the samples may not be completely comparable: for example, the vertical integration in the Japanese firms may be greater, leading to a sample that is less concentrated in the particular sector on which we are focusing our attention.

III. Univariate Time Series Analysis and Some Modeling Issues

The appendix contains a set of explorations into the question of what type of univariate time series process adequately describes the type of data we are analyzing here. The answer to this question is of interest primarily for econometric reasons: it can inform us about the classes of models and error specifications that are likely to provide an adequate summary of the major features of the data. We summarize our findings here and provide a table of results for the samples used which illustrate the identification problem confronted when analyzing short panels using univariate autoregressive models.

The most general model we considered is the following (this is similar to the basic model considered by Holtz-Eakin, Newey, and Rosen (1988)):

$$(1) \quad y_{it} = \alpha_i + \delta_t + \sum_{s=1}^m \beta_{t,s} y_{i,t-s} + \varepsilon_{it} \quad i = 1, \dots, N \text{ firms}; \quad t = 1, \dots, T \text{ years}$$

where y_{it} is the logarithm of the variable in which we are interested. We have $T=12$ and N

approximately 200, so we treat the time effect δ_t as fixed and include a set of time dummies in all estimations. α_i is a permanent unobserved difference across firms. The appendix presents a series of tests for the functional form of this model, based on a slightly different sample of firms. These tests were performed using the full set of linear moment restrictions implied by the structure of the model; that is the number of orthogonality conditions used grows as T^2 . Except for sales and cash flow in Japan (where coefficients were fully nonstationary), we tended to find that the data were well fit by either a fully stationary model or one with a single proportionality coefficient across years:

$$(2) \quad y_{it} = \alpha_i + \delta_t + \sum_{s=1}^m \beta_s y_{i,t-s} + \varepsilon_{it}$$

or

$$(3) \quad y_{it} = \psi_i \alpha_i + \delta_t + \sum_{s=1}^m \beta_s y_{i,t-s} + \varepsilon_{it}$$

or

$$(4) \quad y_{it} = \alpha_i + \delta_t + \lambda_i \left[\sum_{s=1}^m \beta_s y_{i,t-s} \right] + \varepsilon_{it}$$

The data are typically unable to choose between models (3) and (4). The optimal lag length m ranged from 2 to 8, but was usually between 3 and 5. However, in the same appendix, we show the results of GMM estimation using two types of simulated data processes: a model with only a fixed effect and a linear trend (a deterministic trend), and a model of a random walk with drift (a stochastic trend). Our results show that the second model gives reasonable answers

using GMM; although the instruments will be poor in this case, the estimates were correct (within the standard errors). In contrast, the estimates for the first model suffer severely from finite sample bias, which only gets worse as we increase T (the number of years in the panel). For samples of our size, the estimated lag coefficients are halfway between the (very inconsistent) ordinary least squares estimates and the true values of zero. In addition, testing for the order of the lag results in numbers like 5 or more where the truth is 0.

The finite sample problem here appears to arise because the efficient GMM estimator uses a very large number of orthogonality conditions relative to the amount of information in the instruments. Thus in the remainder of the paper, we rely on estimates based on a maximum of 5 lags of each variable as an instrument in any one year, rather than the full set available. This improves the bias, obviously at the cost of increasing the standard errors.

In a general regression model, α_i may or may not be correlated with the regressors. In this case, the question of correlation is not really very interesting; if α_i is there, it is certainly correlated with lagged y . The relevant question is whether the data are well-described by the same autoregressive model where firms differ only in their initial condition, or whether there is a tendency for them to regress toward individual means; that is whether there are permanent unobserved differences across firms.

To answer this question, we estimated an autoregressive model for each data series in two different ways using the Generalized Method of Moments: the first uses only orthogonality conditions between first differences of the model and levels of the lagged variables and is consistent even if there are permanent correlated firm effects. The second uses orthogonality conditions between levels of the model and levels of the lagged dependent

variable and is efficient if there are no firm effects, but inconsistent otherwise. We chose the optimal lag length for each form of the model, and conducted tests at that lag length for the validity of the additional restrictions implied by the equations in levels.

Tables 4a and 4b show the results of this procedure: Table 4a shows it for simulated data and 4b for our actual data. In Table 4a, we consider estimation of data generated by the following processes (in all cases ε_{it} is a white noise process):

$$(5) \quad y_{it} = y_{it-1} + \varepsilon_{it} \quad (\text{Random walk})$$

$$(6) \quad y_{it} = \alpha_i + \varepsilon_{it} \quad (\text{Fixed effect})$$

$$(7) \quad y_{it} = 0.9 y_{it-1} + \varepsilon_{it} \quad (\text{AR}(1))$$

$$(8) \quad y_{it} = \alpha_i + 0.9 y_{it-1} + \varepsilon_{it} \quad (\text{AR}(1) \text{ with fixed effect})$$

$$(9) \quad y_{it} = \alpha_i + 0.3 y_{it-1} + \varepsilon_{it} \quad (\text{AR}(1) \text{ with fixed effect})$$

The fixed effect α_i and the initial conditions were generated from a normal distribution with mean 2 and variance 4. The data generated by these processes were then fit to the model of equation (1) both in level equations (inconsistent in the presence of α_i) and in first differences, with the length of the lag chosen using conventional F-tests. In addition, a test for the presence of firm effects was conducted by testing for the significance of the overidentifying restrictions implied by equation (1) in levels.

From Table 4a, one can see that all models except the simple random walk will correctly

reject or accept the presence of correlated effects at the one or five percent level. However, the p-value for the random walk model is .034, which might lead to rejection of the hypothesis that there are no permanent firm effects even though this hypothesis is true. In a short panel, it will be extremely difficult to tell with confidence whether the process can be described by an autoregressive process with a unit root but no permanent difference across firms, or by a fixed firm effect plus perhaps an autoregressive process with much smaller coefficients.

Turning to the real data, only 3 data series are able to accept unequivocally the absence of firm effects: labor and sales in France and labor in Japan. It is noteworthy that two of these series (labor in Japan and France) are the two that display the least variability out of the entire 15. There are a further 2 where the answer is somewhat ambiguous: R&D in the United States and investment in Japan. Although the results of the testing shown in Table 4b are somewhat inconclusive, we treat them as an indication that most of the data series we are working with need a permanent firm effect in their model and we therefore specify one in the models of the next section.

TABLE 4a
UNIVARIATE TIME SERIES ANALYSIS
SIMULATED DATA

Data Gen. Process	True Coeff	# of Lags	First Difference Estimates			FD and Levels	
			Sum of Lag Coeffs	Test for FE	1st Order Ser. Corr.	# of Lags	Sum of Lag Coeffs
Random Walk	1.0	1	.419(.151)	22.3 (.034)	-.35	1	.987
Firm Eff.	0.0	1	-.036(.037)	87.9 (.000)	-.50	4	.942
AR(1)	0.9	1	.831(.025)	15.5 (.216)	-.50	1	.900
AR(1) with FE	0.9	1	.895(.002)	59.1 (.000)	-.50	6	.639
AR(1) with FE	0.3	1	.279(.031)	62.7 (.000)	-.50	4	.838

Notes to Tables 4a and 4b:

1) In Table 4a, the data generation process is in all cases based on the empirical moments of the U.S. log R&D process. The number of individuals is 200 and the number of time periods is 12, with the same number used for estimation as in Table 4b.

2) First differenced estimates are based on OCs between the first difference of the model and lagged level variables. FD and level estimates are based on OCs between the model in levels and lagged level variables. They are consistent only if the firm effects are not correlated with the variable.

3) The # lags shown is the number arrived at under each model by conventional Wald tests at the 1 percent level. The sum of the lag coefficients is the sum of the estimated lag coefficients at the chosen number of lags.

4) The tests always have 12 degrees of freedom and are tests that there are no firm effects, conducted at the chosen number of lags in each case.

5) The serial correlation is the average correlation of the disturbances in the first differenced model (which are moving average under the conventional interpretation -- that is, except for the random walk model).

TABLE 4b
UNIVARIATE TIME SERIES ANALYSIS

Variable Country	First Difference Estimates				FD and Levels	
	# of Lags	Sum of Lag Coeffs	Test for FE	First Order Ser. Corr.	# of Lags	Sum of Lag Coeffs
Sales						
U.S.	1	.286	40.7 (.000)	-.07	4	.999
France	1	.311	14.1 (.297)	-.25	5	.967
Japan	3	.135	54.5 (.000)	0.04	5	.921
R&D						
U.S.	3	.301	22.6 (.032)	-.18	4	1.014
France	1	.109	47.5 (.000)	-.18	2	.898
Japan	2	.057	75.9 (.000)	-.20	2	.617
Investment						
U.S.	2	.075	42.8 (.000)	-.33	5	.982
France	1	.374	64.4 (.000)	-.45	4	.958
Japan	3	-.662	21.6 (.042)	-.12	4	1.018
Employment						
U.S.	1	.747	72.9 (.000)	-.48	5	.993
France	1	.482	18.9 (.089)	-.31	4	.992
Japan	4	.671	7.0 (.859)	-.07	4	.989
Cash Flow						
U.S.	1	.113	35.3 (.000)	-.23	5	1.011
France	3	-.405	81.3 (.000)	-.01	4	.751
Japan	2	.020	39.6 (.000)	-.25	5	1.004

IV. Bivariate Causality Testing

Based on our experience with univariate modeling, we specify our two variable model for causality testing with a permanent firm effect, and we estimate using a restricted set of lags as instruments. Our maintained model is similar to that in Holtz-Eakin, Newey, and Rosen:

$$(5) \quad y_{it} = \alpha_i + \delta_t + \sum_{s=1}^m \beta_s y_{it-s} + \sum_{s=1}^m \gamma_s x_{it-s} + \varepsilon_{it}$$

$i = 1, \dots, N \text{ firms} \quad t = 1, \dots, T \text{ years (T=12)}$

As before, α_i is a correlated firm effect and δ_t are year dummies. ε_{it} is a serially uncorrelated disturbance (when m is large enough).

After differencing, the appropriate orthogonality conditions for GMM use lagged x 's and y 's as instruments. We use a maximum of 5 lags, based on our experience with finite sample bias in GMM when the full set of orthogonality conditions is used. Our assumptions imply the following set of orthogonality conditions:

$$(6) \quad E [z_{is} \Delta u_{it}] = 0 \quad t = m+2, \dots, T; \quad s = \max(1, t-m-4), \dots, t-m$$

where $\Delta u_{it} = \Delta y_{it} - \Delta \delta_t - \beta \cdot \Delta y_{it-1} - \gamma \cdot \Delta x_{it-1}$ and $z_{is} = [x_{is} \ y_{is}]$. There are $2(9+5(T-m-4))$ orthogonality conditions in (6), plus $T-m-1$ for the year dummies.

Using (6) as our basic specification, we conduct the following tests: First, Arellano and Bover (1994) suggested that lagged Δx 's and Δy 's can be used as instruments for equation

(5) in levels. Blundell and Bond (1995) show that this is valid if the initial deviation ϵ_{i1} is not correlated with the initial level of y , which is proportional to the firm effect α_i . We test for this by adding equation (7) to our estimation and usually accept the restriction:

$$(7) \quad E [\Delta z_{it-1} u_{it}] = 0 \quad t = m+2, \dots, T \quad (2(T-m-1) \text{ additional restrictions})$$

Second, conditional on the results of our test of Blundell and Bond's restriction (notated B-B eq. 4.1 in the tables), we choose the length of the lag m from 2, 3, 4, or 5. At the chosen length, we check that the B-B 4.1 restriction still holds. Once we have a preferred specification, we test for causality with a joint test of the significance of the γ 's. If we accept zero γ 's, then x does not cause y . If we reject, x or a third variable causes y . The results of this procedure for the sales, cash flow, R&D, and investment variables are shown in Appendix B and summarized in Tables 5 and 6.

The tables in Appendix B are organized in the following way: The top panel shows the length of lag m that was chosen, together with the results of the causality tests with and without the B-B 4.1 restriction imposed. We also show the results of the test for the validity of this restriction, which is accepted easily in most cases. The exceptions are the relationship between cash flow and both investment and R&D in Japan, and more weakly, between investment and sales in France and Japan. This implies that in general the random year-to-year disturbances in sales, cash flow, and R&D are not correlated with the initial levels of these variables. In some, but not all, cases, adding the orthogonality conditions implied by B-B 4.1 reduces the standard errors substantially.

Table 5 summarizes the results of the causality testing, choosing the test that is

based on the estimates with B-B 4.1 is imposed where that restriction is accepted at the one percent level, and the other test if it is rejected. The causality tests themselves are not very meaningful in an accept-reject sense, since they almost all reject noncausality; that is, the second (x) variable helps to predict the first (y) variable even in the presence of its own lags, and even if only growth rates are being predicted. The only cases where we can accept non-causality is in France, where sales does not cause investment and Japan, where investment does not cause sales. However, the magnitude of the test statistic and the sum of the lag coefficients on the variables display a large amount of rather systematic variation and are quite informative.

The bottom panels of the tables in Appendix B give the full set of estimated lag coefficients for each bivariate regression, again with and without B-B 4.1 imposed. We summarize these results in Table 6. This table shows the sum of the lag coefficients for the chosen regressions, for each pair of variables, and for each country, 24 regressions in all.

From the perspective of the question we posed at the beginning, the results in Table 6 are very striking: even more than in the case of sales, the U.S. data display a high predictive power of cash flow for both R&D and investment, particularly when contrasted with France and Japan. The coefficients of cash flow in both the R&D and investment regressions are strongly positive in the United States, and very small in the other countries, except for investment in Japan, whose coefficient is half the level of that in the United States. For whatever reason, liquidity or flexibility in the face of demand shocks, large U.S. scientific sector firms seem to be more sensitive to cash flow changes.

At the same time, the role of investment in generating future cash flow appears to be somewhat weaker, possibly zero in Japan and negative in France. The impact of R&D investment on cash flow in the United States and Japan looks similar to ordinary investment in these

countries, but that for France is much higher. It is worth remembering at this point that the French firms do relatively more R&D than investment than the other countries, and may be a somewhat different type of sample.

The sales regressions display the same kind of results, but much weaker: in this case sales growth clearly predicts R&D growth in all three countries, although somewhat more strongly in the United States. The converse is that R&D does not appear to cause future sales growth, except in the United States, and even here the coefficient is small (on the order of .09).¹² Investment appears unrelated to future sales in all three countries.

V. Conclusions

We view these results as very preliminary, but highly suggestive. The oft-told story of a softer budget constraint on investment in the major continental countries and Japan when compared to the United States is clearly supported by our analysis. However we would be extremely cautious about drawing strong conclusions from these data yet, for two quite different sets of reasons. First, findings like those here do not automatically imply that liquidity constraints are at the root of the differences: what we may be seeing is a greater flexibility of firms in the United States in all dimensions when faced with demand shocks; consider the evidence of the employment fluctuations. In addition, we have not fully explored the question of whether the "softer" budget constraint means more or less productive investment, although the evidence of the reverse regressions is slightly daunting

¹²It is worth noting that the magnitude of this coefficient is approximately equal to the estimate obtained using production function estimation with sales growth as the dependent variable and the growth in capital, labor, and R&D capital as the independent variables (see Mairesse and Hall 1995). Thus our estimates here are consistent with the traditional TFP regression approach, but they highlight the fact that the simultaneity that we observed in the relationship between the inputs and output of the production process is much more important running from output to input than from input to output.

in this regard; in many cases we see no positive impact on sales and cash flow from investments as long as four years after they are undertaken.

The other reason for caution is the limited nature of our analysis thus far. First, bivariate regressions may not control properly for changes in other closely related factors; for example, it is more natural to include capital and labor when regressing sales on R&D, and surely investment and R&D are related in their impacts on cash flow. Extensions to this paper will conduct the causality testing in a multivariate setting. Second, we have been extremely cavalier in the use of our cash flow variable, which occasionally takes on negative values (for obvious reasons). Because we are working in logarithms, we have simply dropped these observations (and firms). A better analysis would verify our results using investment rates and profit rates (measured relative to the capital stock, for example).

Third, the data still contain some puzzles: we are not precisely sure how the level of consolidation of the company accounts compares across countries; this matters when we are telling stories about internal and external sources of funds for investment. The French cash flow variable exhibits some anomalous behavior in the early years. Finally, we need to explore the importance of the precise definition of cash flow that we use to our results.

In spite of these caveats, the results to date are highly suggestive, even more so when compared with those of Bond et al (1995) on investment and cash flow in U.K., Belgian, French, and German firms, which show much higher sensitivity of investment to cash flow in the U.K. than in the other three countries.

TABLE 5
CAUSALITY TESTING

	United States	France	Japan
Number of Firms	174	104	200
Does CF cause I?	111.3 (4) **	12.6 (5) *	71.4 (4) **
Does CF cause R?	235.2 (4) **	67.3 (3) **	16.3 (3) **
Does I cause CF?	40.7 (3) **	26.7 (5) **	25.5 (4) **
Does R cause CF?	42.0 (3) **	116.9 (4) **	25.6 (3) **
Number of Firms	204	156	221
Does S cause I?	84.8 (3) **	6.6 (4)	77.6 (4) **
Does S cause R?	200.7 (4) **	133.0 (4) **	57.2 (3) **
Does I cause S?	35.0 (5) **	14.0 (4) **	8.0 (5)
Does R cause S?	39.5 (4) **	13.7 (3) **	38.0 (4) **

In each case, the statistic shown is a chi-squared (degrees of freedom) for the hypothesis that the lagged "causal" variables do not enter the equation once the appropriate lags of the dependent variable are included. That is, the statistic 111.3 (4) is the joint significance of the first 4 lags of Cash Flow in an equation with Investment as the dependent variable and 4 lags of Cash Flow and Investment as the independent variables.

TABLE 6
SUMS OF THE ESTIMATED LAG COEFFICIENTS: BIVARIATE REGRESSIONS

Investment and R&D with Cash Flow

Dep. Var.	Lag Indep. Vars.	United States	France	Japan
Investment	Investment	-.111 (.074)	-.607 (.053)	-.007 (.066)
	Cash Flow	.825 (.086)	.081 (.099)	.411 (.075)
R&D	R&D	.316 (.038)	-.124 (.019)	-.066 (.037)
	Cash Flow	.431 (.031)	.124 (.020)	.042 (.059)
Cash Flow	Cash Flow	.101 (.043)	-.578 (.052)	-.372 (.054)
	Investment	.075 (.038)	-.170 (.080)	.039 (.049)
Cash Flow	Cash Flow	-.235 (.046)	-.303 (.050)	-.413 (.047)
	R&D	.226 (.060)	.345 (.053)	.023 (.028)

Investment and R&D with Sales

Dep. Var.	Lag Indep. Vars.	United States	France	Japan
Investment	Investment	-.008 (.050)	-.192 (.099)	-.183 (.086)
	Sales	.608 (.073)	-.181 (.197)	.171 (.137)
R&D	R&D	-.055 (.053)	.142 (.053)	.167 (.022)
	Sales	.628 (.053)	.536 (.071)	.408 (.057)
Sales	Sales	.562 (.061)	.006 (.068)	.362 (.066)
	Investment	-.127 (.047)	.013 (.025)	.038 (.039)
Sales	Sales	.170 (.062)	.086 (.052)	.705 (.029)
	R&D	.092 (.045)	-.056 (.028)	-.004 (.016)

The table shows the sum of the estimated lag coefficients together with their standard errors in parentheses for the 8 bivariate regressions reported in Table 5, one for each country.

FIGURE 1
Growth Rates for the Median Firm in the Sample

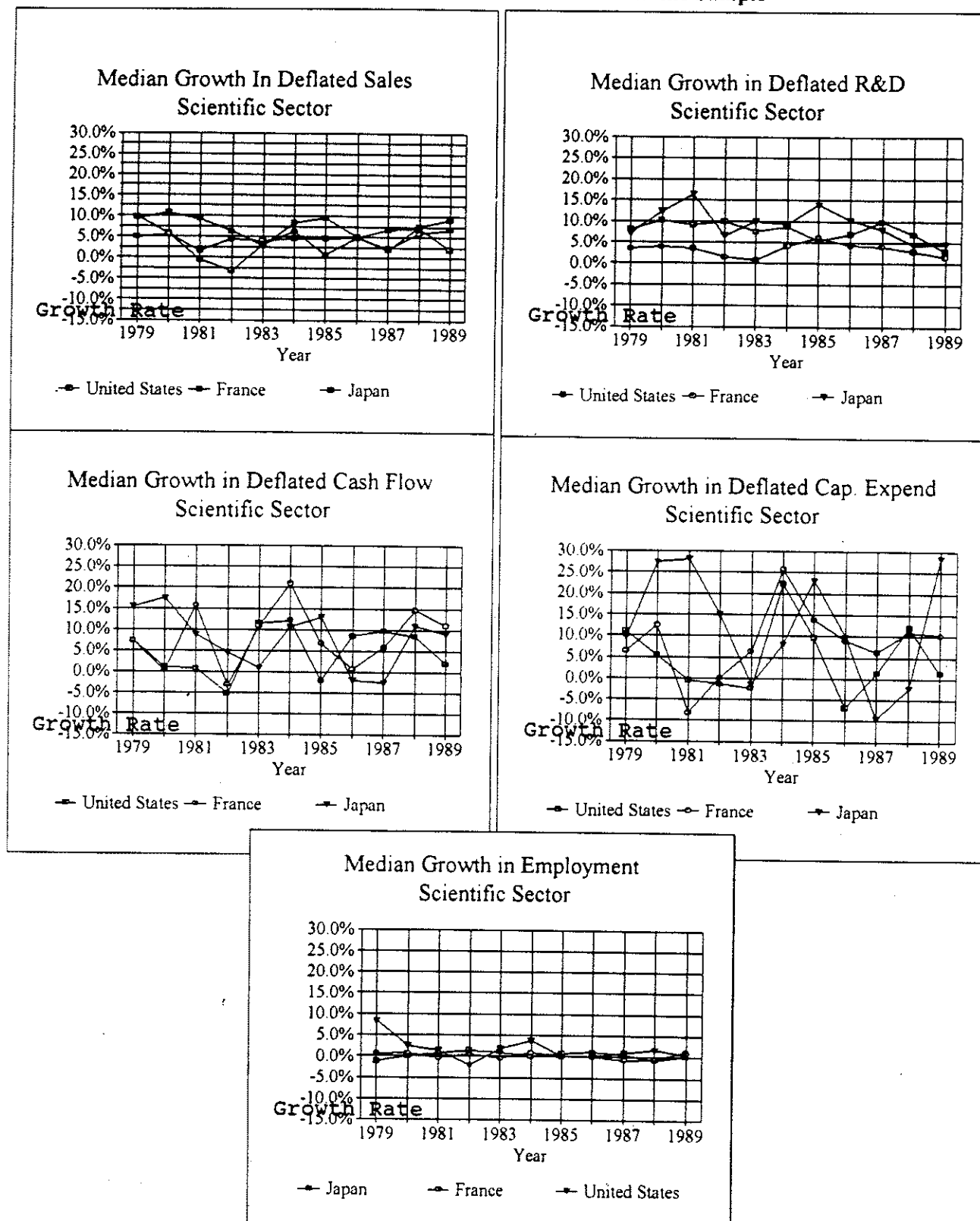


FIGURE 2
Interquartile Ranges for Growth Rates in the Sample

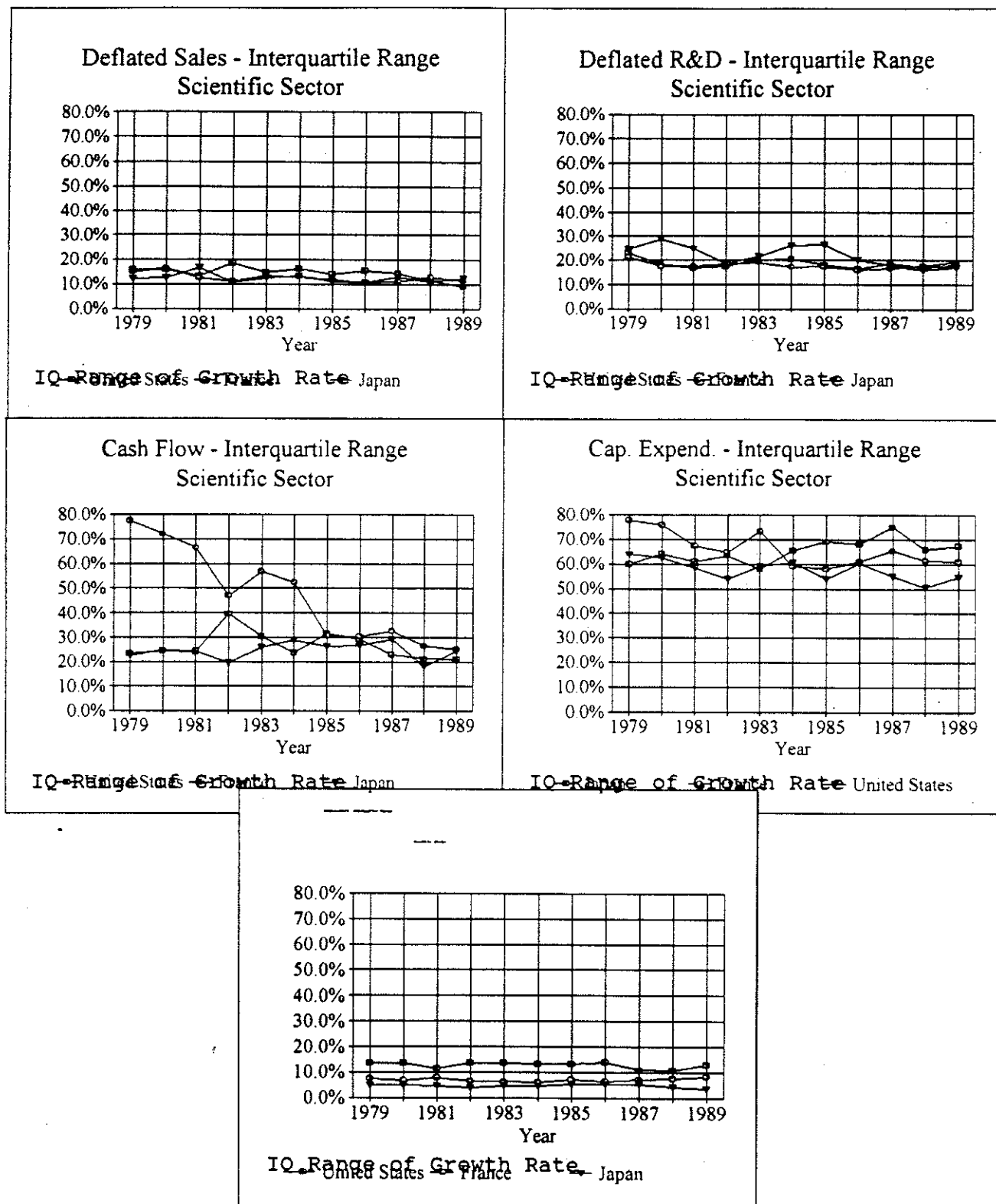
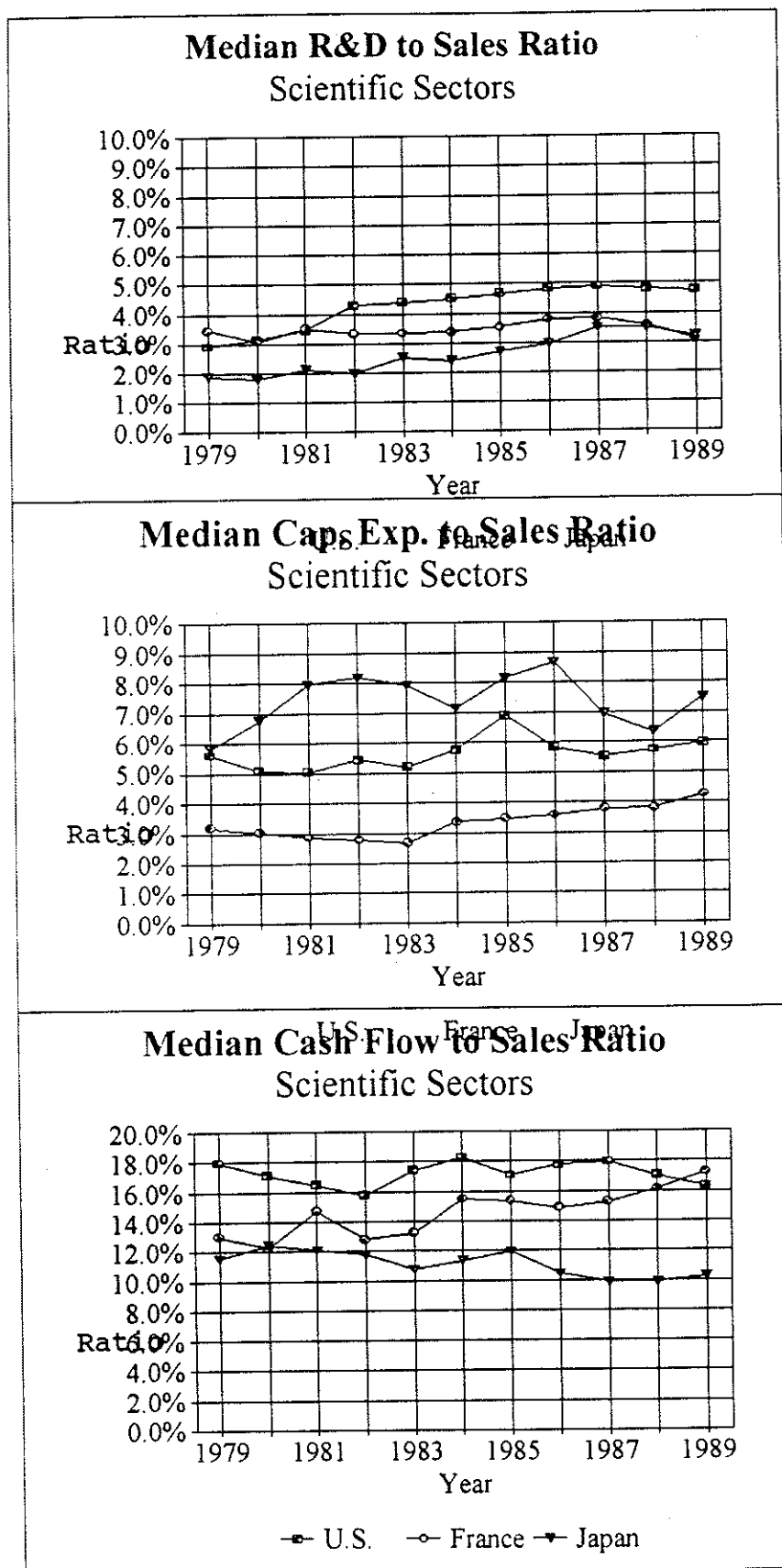


FIGURE 3
Median Ratios for Firms in the Sample



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APPENDIX

UNIVARIATE PANEL DATA MODELS

This appendix describes some of the investigations we did into the univariate time series properties of our key variables, as well as the simulations we used to assess the performance of GMM in estimating these models.

We have 12 years of data available for each variable from 1978-1989, 11 after differencing to eliminate α_i . The maximum number of lags in our autoregressive process is therefore $m=10$. We choose the length of the lag m in each case below by finding the longest set of lags (up to $m=10$) where the last $10-(m+1)$ enter with a p-value greater than .01. Using a Wald or generalized F test. This means we are using a different number of equations for estimation, depending on the maximum order m . The models and tests whose estimates are shown in Tables A.1-A.3 are described below.

1. ONEST: Stationary coefficients.

$$y_{it} = \alpha_i + \delta_i + \sum_{s=1}^m \beta_s y_{i,t-s} + \varepsilon_{it}$$

2. ONEME: Stationary with measurement error. The model is the same as (1), but we need lags from $m+1$ to $2m$ as instruments in this case. This reduces the length of lag that can be investigated to $m=5$.

Test ME: Test the validity of the additional OCs allowed if there is no measurement error (lags 1 to m can be used as instruments).

3. **ONELAM:** Time-varying coefficients for the fixed effect, but constant lag coefficients.

$$y_{it} = \psi_t \alpha_i + \delta_t + \sum_{s=1}^m \beta_s y_{i,t-s} + \varepsilon_{it}$$

Test PSI: $\psi_t = 1$ for all t . (Model 1)

4. **ONELAM2:** Proportional lag coefficients, and a constant fixed effect.

$$y_{it} = \alpha_i + \delta_t + \lambda_t \left[\sum_{s=1}^m \beta_s y_{i,t-s} \right] + \varepsilon_{it}$$

Test LAM: $\lambda_t = 1$ for all t . (Model 1)

5. **ONENS:** Time-varying lag coefficients, and a constant fixed effect.

$$y_{it} = \alpha_i + \delta_t + \sum_{s=1}^m \beta_{t,s} y_{i,t-s} + \varepsilon_{it}$$

Test NS1: $\beta_{t,s} = \beta_s$ for all t . (Model 1)

Test NS2: $\frac{\beta_{t,s}}{\beta_{t-1,s}} = \frac{\beta_{t,r}}{\beta_{t-1,r}}$ for all t and for all r and s .

(Model 4)

TABLE A.2

France - Univariate Time Series - 294 Firms - 1978-1989

Variable	Job	Sales	R&D	Investment	Employment	Profits
Number of Firms		294	294	294	294	N=175
Stationary ($\lambda(t)=1$; $\psi(t)=1$) estimate of lag length m	ONEST	56.2 (45) 4	41.8 (49) 3	64.7 (40) 5	56.0 (34) 6	45.2 (49) 3
Stationary with meas. error estimate of lag length m	ONEME	55.9 (34) 1	31.2 (34) 1	42.0 (34) 1	61.7 (34) 2	53.9 (50) 2
QLR test for no meas. error	test ME	0.967	0.928	0.523	0.423	0.096
Constant lag coeffs. time-varying FE ($\psi(t)$) estimate of lag length m	ONELAM	43.5 (38) 4	29.2 (41) 3	48.3 (34) 5	33.1 (29) 6	33.8 (41) 3
Wald test $\psi(t) = 1$	testPSI	0.100	0.078	0.000	0.003	0.012
QLR test $\psi(t) = 1$	testPSI	0.149	0.126	0.012	0.000	0.180
Proportional lag coeffs. free $\lambda(t)$; $\psi(t) = 1$ estimate of lag length m	ONELAM2	42.8 (38) 4	30.0 (41) 3	48.5 (34) 5	34.0 (29) 6	37.5 (43) 2
Wald test $\lambda(t) = 1$	testLAM	0.969	0.995	0.054	0.000	0.336
QLR test $\lambda(t) = 1$	testLAM	0.709	0.160	0.013	0.001	0.156
Non-stationary with $\psi(t)=1$ estimate of lag length m	ONENS	5.0 (9) 6	20.4 (27) 3	18.2 (9) 6	8.3 (9) 6	23.0 (27) 3
Wald test for stationary coeffs.	testNS1	0.000	0.026	0.000	0.000	0.000
Wald test for proportional coeffs.	testNS2	0.221	0.777	0.016	0.317	0.495
QLR test for proportional coeffs.	testNS2	0.919	0.791	0.124	0.178	0.74

Each model is shown with its J-stat and degrees of freedom for the overidentifying restrictions at the optimal lag.

The tests are shown as P-values (the probability of observing a higher chi-squared under the null hypothesis).

Wald tests are for the constraints implied by the null, evaluated at the alternative.

QLR tests are based on the differences in the chi-squareds of the two models, at the max of the optimal lag length

TABLE A.3

Japan - Univariate Time Series - 372 Firms - 1978-1989

Variable	Job	Sales	R&D	Investment	Employment	Profits
Number of Firms		372	221	372	372	191
Stationary ($\text{lam}(t)=1$; $\text{psi}(t)=1$) estimate of lag length m	ONEST	39.1 (19) 8	63.5 (40) 5	53.0 (27) 7	54.6 (45) 4	54.1 (27) 7
Stationary with meas. error estimate of lag length m	ONEME	28.8 (14) 4	45.9 (34) 2	57.4 (22) 3	20.3 (22) 3	42.1 (24) 3
QLR test for no meas. error	testME	0.024	0.018	0.327	0.047	0.007
Constant lag coeffs time-varying FE ($\text{psi}(t)$) estimate of lag length m	ONELAM	49.4 (23) 7	45.9 (34) 5	61.5 (29) 6	40.3 (34) 5	48.2 (23) 7
Wald test $\text{psi}(t) = 1$	testPSI	0.065	0.000	0.005	0.000	0.007
QLR test $\text{psi}(t) = 1$	testPSI	0.126	0.007	0.024	0.101	0.207
Proportional lag coeffs free $\text{lam}(t)$; $\text{psi}(t) = 1$ estimate of lag length m	ONELAM2	47.4 (23) 7	45.5 (34) 5	41.8 (23) 7	39.1 (38) 4	48.1 (23) 7
Wald test $\text{lam}(t) = 1$	testLAM	0.131	0.005	0.015	0.009	0.032
QLR test $\text{lam}(t) = 1$	testLAM	0.056	0.006	0.024	0.030	0.199
Non-stationary with $\text{psi}(t)=1$ estimate of lag length m	ONENS	0.6 (2) 8	10.4 (14) 5	5.5 (2) 8	10.1 (9) 6	18.2 (9) 6
Wald test for stationary coeffs.	testNS1	0.000	0.000	0.000	0.000	0.000
Wald test for proportional coeffs.	testNS2	0.017	0.473	0.505	0.067	0.000
QLR test for proportional coeffs.	testNS2	0.006	0.02	0.503	0.000	0.006

Each model is shown with its J-stat and degrees of freedom for the overidentifying restrictions at the optimal lag.

The tests are shown as P-values (the probability of observing a higher chi-squared under the null hypothesis).

Wald tests are for the constraints implied by the null, evaluated at the alternative.

QLR tests are based on the differences in the chi-squareds of the two models, at the max of the optimal lag length.

TABLE A.4
SIMULATION RESULTS

Model Estimated: Fixed Effect, Linear Trend, and 5 Lags of Dependent Variable

(1) Data Generation Model: Fixed Effect plus Linear Trend

No. of time periods		6	6	6	6	6	6
No. of observ.	True	385	3000	385	3000	385	3000
Method of Est.	Model	OLS	OLS	IV	IV	GMM	GMM
DY (-1)	0	-.805 (.021)	-.832 (.007)	-.378 (.517)	-.351 (.358)	-.429 (.084)	-.041 (.034)
DY (-2)	0	-.640 (.026)	-.666 (.009)	-.312 (.399)	-.283 (.286)	-.357 (.069)	-.026 (.029)
DY (-3)	0	-.446 (.027)	-.508 (.010)	-.195 (.305)	-.220 (.214)	-.238 (.034)	-.036 (.022)
DY (-4)	0	-.307 (.026)	-.340 (.009)	-.148 (.194)	-.144 (.146)	-.167 (.040)	-.019 (.016)
DY (-5)	0	-.135 (.021)	-.167 (.007)	-.050 (.105)	-.067 (.075)	-.067 (.026)	-.002 (.010)
Sum	0	-2.333	-2.513	-1.083	-1.067	-1.26 (.26)	-.133 (.166)
Trend	0.06	.196 (.008)	.213 (.003)	.123 (.088)	.125 (.066)	.132 (.016)	.069 (.007)
s.e. (R2)		.276 (.400)	.278 (.416)	.300 (.396)	.309 (.416)		
Chisq (DF)						68.5 (45)	43.2 (45)

(1) Data Generation Model: Fixed Effect plus Linear Trend

No. of time periods		20	20	20	20	20	20
No. of observ.	True	385	1000	385	1000	385	1000
Method of Est.	Model	OLS	OLS	IV	IV	GMM	GMM
DY (-1)	0	-.848 (.011)	-.839 (.007)	-.113 (.760)	.030 (.035)	-.719 (.018)	-.151 (.015)
DY (-2)	0	-.657 (.014)	-.670 (.009)	-.057 (.620)	.032 (.030)	-.566 (.016)	-.123 (.013)
DY (-3)	0	-.488 (.015)	-.499 (.009)	-.051 (.452)	.027 (.024)	-.395 (.012)	-.086 (.011)
DY (-4)	0	-.319 (.014)	-.321 (.009)	-.029 (.300)	.032 (.018)	-.254 (.010)	-.046 (.009)
DY (-5)	0	-.159 (.011)	-.151 (.007)	-.020 (.145)	.021 (.012)	-.131 (.007)	-.020 (.007)
Sum	0	-2.471	-2.48	-0.27	0.142	-2.07 (.06)	-.427 (.050)
Trend	0.06	.213 (.004)	.212 (.003)	.078 (.141)	.052 (.007)	.186 (.004)	.087 (.003)
s.e. (R2)		.276 (.423)	.276 (.418)	.344 (.389)	.367 (.295)		
Chisq (DF)						318.5 (279)	320.6 (279)

(1) Firm Effects are N(1.9,2.1).

TABLE A.5
SIMULATION RESULTS

Model Estimated: Fixed Effect, Linear Trend, and 5 Lags of Dependent Variabl

(2) Data Generation Model: Random Walk with Drift

No. of Time Periods		6	6	6	6	6	6
No. of Observ.	True	385	3000	385	3000	385	3000
Method of Est.	Model	OLS	OLS	IV	IV	GMM	GMM
DY (-1)	0	.002 (.021)	.002 (.007)	3.19 (12.5)	.893 (2.11)	.087 (.126)	-.005 (.126)
DY (-2)	0	.006 (.021)	.002 (.007)	-.012 (.099)	.003 (.010)	.007 (.020)	.003 (.007)
DY (-3)	0	.016 (.021)	.006 (.007)	.045 (.133)	.007 (.011)	.010 (.020)	.005 (.007)
DY (-4)	0	.004 (.021)	-.019 (.007)	-.064 (.273)	-.028 (.024)	.016 (.018)	-.018 (.007)
DY (-5)	0	-.023 (.021)	.001 (.007)	-.051 (.130)	.013 (.031)	-.031 (.019)	-.000 (.007)
Sum	0	0.005	-0.009	3.05	0.888	.089 (.129)	-.016 (.128)
Trend	0.06	.054 (.006)	.060 (.002)	-.113 (.654)	.005 (.130)	.049 (.008)	.061 (.008)
s.e. (R2)		.253 (.001)	.256 (.000)	.849 (.000)	.342 (.000)		
Chisq (DF)						46.2 (45)	51.1 (45)

(2) Data Generation Model: Random Walk with Drift

No. of Time Periods		20	20	20	20	20	20
No. of Observ.	True	385	1000	385	1000	385	1000
Method of Est.	Model	OLS	OLS	IV	IV	GMM	GMM
DY (-1)	0	-.001 (.011)	-.006 (.007)	-.801 (9.34)	.238 (.708)	-.007 (.031)	-.010 (.048)
DY (-2)	0	-.004 (.011)	-.006 (.007)	-.005 (.017)	-.006 (.007)	-.003 (.006)	-.009 (.006)
DY (-3)	0	-.017 (.011)	.009 (.007)	-.023 (.069)	.010 (.008)	-.018 (.006)	.007 (.006)
DY (-4)	0	.010 (.011)	.012 (.007)	-.004 (.167)	.011 (.008)	.001 (.005)	.012 (.006)
DY (-5)	0	-.008 (.011)	-.004 (.007)	-.001 (.082)	-.007 (.011)	-.002 (.006)	-.011 (.006)
Sum	0	-.020	0.005	-.834	0.246	-.028 (.035)	-.011 (.048)
Trend	0.06	.055 (.003)	.061 (.002)	.100 (.527)	.046 (.043)	.055 (.002)	.061 (.003)
s.e. (R2)		.253 (.000)	.255 (.000)	.325 (.000)	.263 (.000)		
Chisq (DF)						283.4 (279)	299.9 (279)

(2) Initial condition is $N(1,9,2,1)$.

In all cases, a Hausman test for uncorrelated effects rejects.

TABLE 5a
DOES CASH FLOW CAUSE INVESTMENT?

Country	m	Causality w/o 4.1	Test for B-B eq 4.1	Causality with 4.1
US (174)	4 or 5	32.0 (5) **	9.9 (13)	111.3 (4) **
France (104)	5	5.9 (5)	11.8 (11)	12.6 (5) *
Japan (200)	4	34.6 (4) **	9.6 (13)	71.4 (4) **

Chi-squared tests with degrees of freedom in parentheses. ** denotes significance at the 1% level and * at the 5% level.

Estimated Coefficients of the Lag Variables (Dep. Var. is Investment)

Country	Without 4.1		Lag	With 4.1	
	Investment	Cash Flow		Investment	Cash Flow
US	-.110 (.057)	.333 (.107)	1	.183 (.033)	.434 (.046)
	-.287 (.031)	.158 (.040)	2	-.211 (.021)	.070 (.025)
	-.121 (.038)	.185 (.040)	3	.009 (.028)	.153 (.033)
	-.085 (.032)	.220 (.048)	4	-.093 (.018)	.168 (.025)
	-.085 (.023)	.090 (.037)	5	-	-
	-.688 (.144)	1.006 (.198)	Sum	-.111 (.074)	.825 (.086)
France	-.162 (.051)	.027 (.089)	1	.006 (.043)	-.011 (.053)
	-.309 (.037)	.024 (.028)	2	-.373 (.031)	-.009 (.033)
	-.185 (.028)	.049 (.024)	3	-.136 (.022)	.046 (.019)
	-.116 (.026)	.050 (.020)	4	-.062 (.026)	.032 (.025)
	-.081 (.025)	.032 (.020)	5	-.106 (.025)	.022 (.018)
	-.853 (.126)	.182 (.149)	Sum	-.607 (.053)	.081 (.099)
Japan	-.077 (.051)	.279 (.080)	1	.172 (.034)	.346 (.057)
	-.206 (.032)	.034 (.041)	2	-.097 (.024)	-.025 (.035)
	-.095 (.023)	-.017 (.037)	3	-.035 (.020)	-.060 (.033)
	-.088 (.020)	.178 (.038)	4	-.046 (.019)	.150 (.032)
	-.467 (.104)	.474 (.124)	Sum	-.007 (.066)	.411 (.075)

TABLE 5b
DOES CASH FLOW CAUSE R&D?

Country	m	Causality w/o 4.1	Test for B-B eq 4.1	Causality with 4.1
US (174)	4	127.2 (4) **	8.6 (13)	235.2 (4) **
France (104)	3 or 4	18.7 (4) **	14.1 (15)	67.1 (3) **
Japan (200)	2 or 3	16.3 (3) **	26.1 (15) *	21.6 (3) **

Chi-squared tests with degrees of freedom in parentheses. ** denotes significance at the 1% level and * at the 5% level.

Estimated Coefficients of the Lag Variables (Dep. Var. is R&D)

Country	Without 4.1		Lag	With 4.1	
	R&D	Cash Flow		R&D	Cash Flow
US	.216 (.049)	.182 (.022)	1	.304 (.060)	.240 (.020)
	-.057 (.019)	.083 (.012)	2	-.100 (.022)	.059 (.017)
	.042 (.013)	.058 (.010)	3	-.054 (.016)	.087 (.012)
	.023 (.012)	.094 (.010)	4	.111 (.049)	.158 (.016)
	.224 (.045)	.416 (.040)	Sum	.316 (.038)	.431 (.031)
France	-.141 (.034)	.089 (.016)	1	-.128 (.015)	.081 (.012)
	-.025 (.011)	.022 (.011)	2	-.013 (.005)	.025 (.007)
	.008 (.011)	-.004 (.008)	3	.016 (.005)	.018 (.005)
	.002 (.008)	.009 (.005)	4		
	-.126 (.054)	.125 (.037)	Sum	-.124 (.019)	.124 (.020)
Japan	.028 (.025)	-.022 (.037)	1	.216 (.017)	.055 (.025)
	-.035 (.014)	.058 (.017)	2	-.014 (.012)	.069 (.015)
	-.058 (.012)	.005 (.017)	3		
			4		
	-.066 (.037)	.042 (.059)	Sum	.202 (.015)	.124 (.020)

Table 6a
DOES INVESTMENT CAUSE CASH FLOW?

Country	m	Causality w/o 4.1	Test for B-B eq 4.1	Causality with 4.1
US (174)	3	20.4 (3) **	9.8 (15)	40.7 (3) **
France (104)	5	19.2 (5) **	6.5 (11)	26.7 (5) **
Japan (200)	4	25.5 (4) **	30.1 (13) **	25.5 (4) **

Chi-squared tests with degrees of freedom in parentheses. ** denotes significance at the 1% level and * at the 5% level.

Estimated Coefficients of the Lag Variables (Dep. Var. is Cash Flow)

Country	Without 4.1		Lag	With 4.1	
	Cash Flow	Investment		Cash Flow	Investment
US	.067 (.038)	.008 (.028)	1	.203 (.030)	.005 (.023)
	-.091 (.017)	-.001 (.014)	2	-.104 (.015)	.002 (.013)
	-.019 (.015)	.050 (.013)	3	.002 (.013)	.068 (.011)
	-.043 (.056)	.057 (.046)	Sum	.101 (.043)	.075 (.038)
France	-.275 (.054)	.010 (.024)	1	-.261 (.043)	-.018 (.036)
	-.152 (.031)	.019 (.008)	2	-.117 (.025)	-.015 (.019)
	-.106 (.020)	-.012 (.005)	3	-.104 (.017)	.054 (.020)
	-.072 (.014)	-.035 (.016)	4	-.077 (.012)	-.053 (.014)
	-.065 (.013)	-.026 (.011)	5	-.069 (.012)	-.030 (.009)
	-.670 (.096)	-.044 (.090)	Sum	-.578 (.052)	-.170 (.080)
Japan	-.057 (.035)	-.023 (.025)	1	.050 (.033)	-.031 (.025)
	-.237 (.029)	.011 (.012)	2	-.230 (.017)	-.003 (.013)
	-.082 (.018)	.013 (.012)	3	-.067 (.017)	-.013 (.011)
	.004 (.018)	.040 (.009)	4	.052 (.017)	.031 (.009)
	-.372 (.054)	.039 (.049)	Sum	-.195 (.052)	-.015 (.049)

Table 6b
DOES R&D CAUSE CASH FLOW?

Country	m	Causality w/o 4.1	Test for B-B eq 4.1	Causality with 4.1
US (174)	3	49.5 (2) **	13.9 (13)	42.0 (3) **
France (104)	4	60.2 (4) **	12.2 (13)	116.9 (4) **
Japan (200)	3	25.6 (3) **	31.0 (15) **	32.5 (3) **

Chi-squared tests with degrees of freedom in parentheses. ** denotes significance at the 1% level and * at the 5% level.

Estimated Coefficients of the Lag Variables (Dep. Var. is Cash Flow)

	Without 4.1			With 4.1	
Country	Cash Flow	R&D	Lag	Cash Flow	R&D
US	-.154 (.029)	.137 (.068)	1	-.124 (.028)	.170 (.092)
	-.086 (.019)	.083 (.022)	2	-.075 (.017)	.092 (.020)
	-.033 (.013)	-.008 (.019)	3	-.037 (.010)	-.036 (.015)
			4		
	-.273 (.058)	.211 (.075)	Sum	-.235 (.046)	.226 (.060)
France	-.143 (.041)	.361 (.068)	1	-.103 (.032)	.416 (.049)
	-.161 (.018)	.047 (.023)	2	-.174 (.013)	.028 (.016)
	-.065 (.012)	-.023 (.022)	3	-.053 (.010)	-.020 (.014)
	.002 (.010)	-.091 (.017)	4	.029 (.009)	-.079 (.012)
	-.366 (.054)	.294 (.077)	Sum	-.303 (.050)	.345 (.053)
Japan	-.093 (.030)	-.023 (.020)	1	-.107 (.071)	-.014 (.016)
	-.201 (.017)	.050 (.010)	2	-.210 (.034)	.049 (.009)
	-.119 (.016)	-.003 (.009)	3	-.122 (.028)	.010 (.009)
			4		
	-.413 (.047)	.023 (.028)	Sum	-.438 (.042)	.044 (.023)

TABLE 8a
DOES INVESTMENT CAUSE SALES?

Country	m	Causality w/o 4.1	Test for B-B eq 4.1	Causality with 4.1
US (204)	5	23.0 (5) **	9.1 (11)	35.0 (5) **
France (156)	4 or 5	14.0 (4) **	20.0 (11) *	18.7 (5) **
Japan (221)	5	8.0 (5)	21.0 (11) *	23.0 (5) **

Chi-squared tests with degrees of freedom in parentheses. ** denotes significance at the 1% level and * at the 5% level.

Estimated Coefficients of the Lag Variables (Dep. Var. is Sales)

Country	Without 4.1		Lag	With 4.1	
	Sales	Investment		Sales	Investment
US	.236 (.049)	-.016 (.019)	1	.213 (.042)	-.026 (.019)
	.072 (.024)	-.028 (.011)	2	.124 (.023)	-.032 (.011)
	.040 (.022)	-.015 (.011)	3	.078 (.021)	-.024 (.011)
	.098 (.020)	-.008 (.007)	4	.093 (.019)	-.010 (.007)
	.042 (.020)	-.028 (.008)	5	.054 (.019)	-.035 (.007)
	.488 (.067)	-.096 (.048)	Sum	.562 (.061)	-.127 (.047)
France	-.021 (.061)	.002 (.012)	1	-.070 (.069)	-.019 (.017)
	-.053 (.019)	.008 (.007)	2	.056 (.020)	.004 (.009)
	.020 (.015)	.008 (.005)	3	.072 (.017)	-.004 (.008)
	.061 (.021)	-.006 (.004)	4	.072 (.024)	-.008 (.007)
	- -	- -	5	-.035 (.024)	-.013 (.005)
	.006 (.068)	.013 (.025)	Sum	-.016 (.077)	-.039 (.040)
Japan	.074 (.069)	.009 (.013)	1	.017 (.064)	.011 (.012)
	-.104 (.034)	.001 (.009)	2	-.090 (.031)	-.006 (.009)
	.091 (.025)	.015 (.008)	3	.166 (.024)	.015 (.007)
	.134 (.026)	.005 (.008)	4	.126 (.026)	.003 (.007)
	.166 (.026)	.008 (.006)	5	.178 (.024)	.012 (.006)
	.362 (.066)	.038 (.039)	Sum	.398 (.060)	.035 (.036)

TABLE 8b
DOES R&D CAUSE SALES?

Country	m	Causality w/o 4.1	Test for B-B eq 4.1	Causality with 4.1
US (204)	4	27.2 (4) **	7.7 (13)	39.5 (4) **
France (156)	3	3.8 (3)	22.7 (15)	13.7 (3) **
Japan (221)	4	10.2 (4) *	13.0 (13)	38.0 (4) **

Chi-squared tests with degrees of freedom in parentheses. ** denotes significance at the 1% level and * at the 5% level.

Estimated Coefficients of the Lag Variables (Dep. Var. is Sales)

Country	Without 4.1		Lag	With 4.1	
	Sales	R&D		Sales	R&D
US	.161 (.048)	-.006 (.035)	1	.128 (.043)	-.023 (.034)
	-.064 (.018)	.047 (.011)	2	-.042 (.018)	.047 (.011)
	.012 (.020)	.022 (.011)	3	.040 (.019)	.036 (.010)
	.056 (.019)	.026 (.009)	4	.044 (.018)	.032 (.009)
	.165 (.064)	.089 (.046)	Sum	.170 (.062)	.092 (.045)
France	-.015 (.044)	-.019 (.024)	1	-.063 (.043)	-.060 (.024)
	.043 (.009)	.004 (.008)	2	.074 (.016)	-.007 (.006)
	.046 (.013)	.010 (.005)	3	.075 (.011)	.011 (.005)
			4		
	.073 (.054)	-.005 (.029)	Sum	.086 (.052)	-.056 (.028)
Japan	.473 (.043)	-.003 (.015)	1	.679 (.036)	.009 (.012)
	-.122 (.026)	-.007 (.005)	2	-.163 (.026)	-.015 (.004)
	.040 (.023)	.006 (.004)	3	.075 (.024)	.018 (.005)
	.138 (.022)	-.013 (.007)	4	.113 (.018)	-.016 (.004)
	.533 (.040)	-.016 (.020)	Sum	.705 (.029)	-.004 (.016)

