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Working Paper

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Jena Economic Research Papers, No. 2008,039

Provided in Cooperation with:
Max Planck Institute of Economics

Suggested Citation: Coad, Alex; Rao, Rekha; Tamagni, Federico (2008) : Growth processes of Italian manufacturing firms, Jena Economic Research Papers, No. 2008,039, Friedrich Schiller University Jena and Max Planck Institute of Economics, Jena

This Version is available at:
https://hdl.handle.net/10419/25721

JENA ECONOMIC RESEARCH PAPERS

2008 – 039

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www.jenecon.de

ISSN 1864-7057

The JENA ECONOMIC RESEARCH PAPERS is a joint publication of the Friedrich Schiller University and the Max Planck Institute of Economics, Jena, Germany. For editorial correspondence please contact m.pasche@wiwi.uni-jena.de.

Impressum:

Friedrich Schiller University Jena
Carl-Zeiss-Str. 3
D-07743 Jena
www.uni-jena.de

Max Planck Institute of Economics
Kahlaische Str. 10
D-07745 Jena
www.econ.mpg.de

Jena Economic Research Papers 2008-039

Growth processes of Italian manufacturing firms*

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Abstract

We apply a reduced-form vector autoregression model to analyze the growth processes of Italian manufacturing firms, 1989-1997. We focus in particular on lead-lag associations describing the coevolution of employment growth, sales growth, growth of profits and labour productivity growth. Employment growth precedes sales growth and growth of profits, and in turn sales growth is also associated with subsequent profits growth. There appears to be little feedback of either sales or profits on employment growth, however. There is no clear association of employment growth with subsequent changes in labour productivity, although at the second lag there is a small negative association. Productivity growth, however, is positively associated with subsequent growth of employment and sales. Quantile autoregressions find asymmetries between growth processes for growing and shrinking firms.

JEL codes: L25, L20

Keywords: Firm Growth, Panel VAR, Employment Growth, Industrial Dynamics, Productivity Growth

*We thank Mercedes Teruel Carrizosa, Marcus Linhardt and Ulrich Witt for helpful comments. This research could have not been possible without the valuable collaboration of the Italian Statistical Office (ISTAT-Industrial Statistics Division), and in particular of A. Mancini and R. Monducci. The data were accessed on site at the ISTAT offices in Rome. The usual caveat applies.

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1 Introduction

Conventional empirical work on firm growth, it would appear, has come to a dead end. A very large literature investigating Gibrat's law has not provided conclusive results on whether firm size is in fact a determinant of firm growth. While many studies detect a statistically significant negative influence of size on growth (although often insignificant in practical terms), many others find no such relation. Other work has investigated what one might call 'augmented Gibrat's law' regressions, which usually involves appending other variables in levels on a Gibrat regression equation, and seeing if these are associated with firm growth. Although coefficients for these additional variables are often statistically significant (especially with large samples) the main conclusion that appears to emerge is that firm growth is a random process, and that its determinants are difficult to find (see Coad (2007d) for a survey). Most of the variance of firm growth rates over time is within-firm variance, rather than between-firm variance (Geroski and Gugler (2004)). Summing up, Geroski even goes as far as to say: "The most elementary 'fact' about corporate growth thrown up by econometric work on both large and small firms is that firm size follows a random walk" (Geroski, 2000, p. 169).

This paper aims to provide new insights into firm growth by taking a different econometric approach. While previous work on firm growth has implicitly assumed employment growth and sales growth to be almost synonymous and interchangeable proxies for firm growth, here we show that these variables are only weakly correlated between themselves, and instead we view them as two distinct variables.[1] Although no one indicator is the 'best', both of them are useful as they shed light on different aspects of firm growth. We consider how they change in relation to each other as well as in relation to other indicators of firm performance, i.e. growth of profits or labour productivity. Previous theoretical work on firm growth has, in fact, often viewed firm growth as related to firm performance. Penrose (1959) suggests a negative relationship between firm growth and productivity growth, because expansion projects are a distraction for managers and divert their attention from keeping operating costs down (the so-called 'Penrose effects'). Other influential theorists, such as Nelson and Winter (1982) and Metcalfe (1994), posit a positive association between profits or productivity and subsequent firm growth, according to the evolutionary principle of 'growth of the fitter'. Perhaps surprisingly, the existing literature on firm growth has not sought to test these theories. The empirical framework presented here, however, is a suitable test bed.

Our results indicate that employment growth precedes sales growth and growth of profits, and that in turn sales growth is also associated with subsequent profits growth. There appears to be little feedback of either sales or profits on employment growth, however. There is no clear association of employment growth with subsequent changes in labour productivity, although

[1] See also Little (1962), who considers that growth of profits can also be taken as a measure of firm growth.

at the second lag there is a small negative association. Productivity growth, however, is positively associated with subsequent growth of employment and sales.

In Section 2 we present the database along with some summary statistics. In Section 3 we discuss our regression methodology. In Section 4 we present our main results. An extended analysis is explored in Section 5, and quantile autoregression techniques are applied to investigate asymmetries in the growth process between growing and shrinking firms in Section 5.5. We conclude in Section 6.

2 Database and summary statistics

This study draws upon the MICRO.1 databank created by the Italian Statistical Office (ISTAT).[2] MICRO.1 contains balance sheets entries of a panel of several thousands of Italian firms, over around a decade (1989 to 1997). In MICRO.1 only firms with 20 or more employees are considered, and different businesses inside the same firm are assigned to the firm's primary activity.[3] Since the panel is open, due to entry, exit, fluctuations around the 20 employees threshold and variability in response rates, we consider only continuing firms over this period. To start with we had observations for around 22'000 firms per year for each year of the period, but at this stage we have a balanced panel of 5536 firms for each year.

In order to avoid misleading values and the generation of NANs[4] whilst taking logarithms and ratios, we now retain only those firms with strictly positive values for Sales, Value Added, Gross Operating Surplus (GOS),[5] and employees in each year. This creates some missing values, hence we observe a different number of observations for different years in Tables 1 and 2).

In keeping with previous studies, our measure of growth rates is calculated by taking the differences of the logarithms of size:

$$GROWTH_{it} = log(X_{it}) - log(X_{i,t-1}) \tag{1}$$

where, to begin with, X is measured in terms of employment, sales, gross operating surplus, or labour productivity[6] for firm i at time t. In keeping with previous work (e.g. Bottazzi et al. (2007), Bottazzi et al. (2008)) the growth rate distributions have been normalized around zero

[2]The database has been made available to one of the coauthors under the mandatory condition of censorship of any individual information.

[3]This operation is performed directly by ISTAT; hence we do not have specialization ratios.

[4]NAN is shorthand for Not a Number, which refers to the result of a numerical operation which cannot return a valid number value. In our case, we may obtain a NAN if we try to take the logarithm of a negative number, or if we try to divide a number by zero.

[5]GOS is referred to as 'profits' in the following.

[6]Labour productivity is calculated in the usual way by dividing Value Added by the number of employees.

Table 1: Summary statistics after cleaning the data

	Mean	Std. Dev.	10%	25%	Median	75%	90%	obs.
1990								
Sales	55152.07	614164.50	2982	4841.5	9893.5	22839.5	60520	2844
Empl	264.77	2688.84	27	35	57	120	320	2844
1993								
Sales	42826.89	238335.40	2981	5184	10901	25070	67218	4897
Empl	161.64	629.47	27	34	54	106	263	4897
1997								
Sales	71515.18	667901.50	3876	6938.5	15189.5	37426.5	96321	4736
Empl	183.96	1110.54	27	35	60	119	282	4736

Table 2: Summary statistics for the growth rate series

	Mean	Std Dev	10%	25%	50%	75%	90%	obs
1990								
Empl growth	0.0000	0.1312	-0.1110	-0.0576	-0.0150	0.0401	0.1291	2770
Sales growth	0.0000	0.3067	-0.2177	-0.1041	-0.0053	0.0980	0.2072	2770
GOS growth	0.0000	0.5297	-0.5218	-0.2165	0.0266	0.2351	0.4841	2770
Prod growth	0.0000	0.1808	-0.1938	-0.0904	0.0042	0.0911	0.1977	2770
1993								
Empl growth	0.0000	0.1131	-0.0963	-0.0410	0.0055	0.0383	0.0925	4704
Sales growth	0.0000	0.3392	-0.2285	-0.1032	0.0012	0.1082	0.2328	4704
GOS growth	0.0000	0.6441	-0.6262	-0.2601	0.0126	0.2810	0.6406	4704
Prod growth	0.0000	0.1851	-0.2052	-0.0987	-0.0054	0.0967	0.2121	4704
1997								
Empl growth	0.0000	0.1278	-0.1103	-0.0515	-0.0118	0.0415	0.1160	4538
Sales growth	0.0000	0.3309	-0.1949	-0.0874	0.0023	0.0851	0.1882	4538
GOS growth	0.0000	0.6408	-0.6038	-0.2474	0.0002	0.2444	0.6338	4538
Prod growth	0.0000	0.2538	-0.2156	-0.0815	0.0220	0.1186	0.2262	4538

in each year which effectively removes any common trends such as inflation.[7]

2.1 Summary statistics

Table 1 presents some year-wise summary statistics, which gives the reader a rough idea of the range of firm sizes in our dataset. Table 2 presents some summary statistics of the growth rate distributions. The summary statistics on growth rates corroborate previous work (Bottazzi et al. (2007)) which showed that the growth rate distributions of Italian firms are heavy-tailed and can be represented by the Laplace distribution (also known as the symmetric exponential

[7]In fact, this choice of strategy for deflating our variables was to some extent imposed upon us, since we were unable to find a suitable sector-by-sector series of producer price indices to be used as deflators.

Table 3: Matrix of contemporaneous correlations for the indicators of firm growth. Conventional correlation coefficients are presented first, followed by Spearman's rank correlation coefficients.

	Empl. growth	Sales growth	GOS growth	Prod. growth
Empl. growth	1.0000			
p-value	0.0000			
obs.	31535			
(Sp. Rank)	1.0000			
(p-value)	0.0000			
Sales growth	0.1854	1.0000		
p-value	0.0000	0.0000		
obs.	31535	31535		
(Sp. Rank)	0.2859	1.0000		
(p-value)	0.0000	0.0000		
GOS growth	0.0992	0.2558	1.0000	
p-value	0.0000	0.0000	0.0000	
obs.	31535	31535	31535	
(Sp. Rank)	0.1135	0.4698	1.0000	
(p-value)	0.0000	0.0000	0.0000	
Prod. growth	-0.2680	0.2417	0.6377	1.0000
p-value	0.0000	0.0000	0.0000	0.0000
obs.	31535	31535	31535	31535
(Sp. Rank)	-0.2232	0.4161	0.7666	1.0000
(p-value)	0.0000	0.0000	0.0000	0.0000

distribution). This suggests that standard regression estimators such as OLS, which assume Gaussian residuals, may perform less well than Least Absolute Deviation (LAD) techniques which are robust to extreme observations. We also observe that the distribution of growth rates of gross operating surplus has a particularly wide support, which would indicate considerable heterogeneity between firms in terms of the dynamics of their profits.

Table 3 shows the correlations between our indicators of firm growth and firm performance. Spearman's rank correlation coefficients are also shown since these are more robust to outliers.

All of the series are correlated between themselves at levels that are highly significant. However, the correlations are indeed far from perfect, as has been noted by Delmar et al. (2003). The largest correlation (0.6377) is between growth of gross operating surplus and that of labour productivity. Indeed, the large positive correlation between profits and productivity has also been observed elsewhere in work on Italian data (Bottazzi et al. (2006)). This might be a problem given that correlations of > 0.7 are usually identified as being problematic – we investigate this potential source of error in Section 5.1.

We also observe significant positive correlations between other pairs of variables, such as between these two variables and the growth of sales (0.2558 and 0.2417 respectively). The

simple correlation between employment growth and labour productivity growth is -0.2680, which is slightly higher than the corresponding statistic observed for French data ((Coad, 2007c, Table 3)).

Although there is some degree of multicollinearity between these series, the lack of persistence in firm growth rates (despite a high degree of persistence of firm size) will, we hope, aid in identification in the regression analysis. Furthermore, the large number of observations will also be helpful in identification. Multicollinearity has the effect of making the coefficient estimates unreliable in the sense that they may vary considerably from one regression specification to another. With this in mind, we therefore pursue a relatively lengthy robustness analysis in Section 5.

3 Methodology

Introducing the VAR The regression equation of interest is of the following form:

$$w_{it} = c + \beta w_{i,t-1} + \varepsilon_{it} \tag{2}$$

where w_{it} is an $m \times 1$ vector of random variables for firm i at time t. β corresponds to an $m \times m$ matrix of slope coefficients that are to be estimated. In our particular case, m=4 and corresponds to the vector (Empl. growth(i,t), Sales growth (i,t), GOS growth (i,t), labour productivity growth(i,t))'. ε is an $m \times 1$ vector of disturbances. Given that our variables are expressed in differences (i.e. growth rates), we avoid issues related to individual-specific time-invariant components as well as technicalities related to unit-root processes.

We do not include any dummy control variables (such as year dummies or industry dummies) in the VAR equation because we anticipate that, if indeed there are any temporal or sectoral effects at work, then dummy variables will be of limited use in detecting these effects. Instead, we suspect that the specificities of individual years or sectors may have non-trivial consequences on the structure of interactions of the VAR series, and these cannot be detected through the use of appended dummy variables alone. We explore the influence of temporal disaggregation and sector of activity in detail in Section 5. Furthermore, since previous work on Italian manufacturing firms has not observed any dependence of sales growth on size (Bottazzi et al. (2007)), our main regression analysis does not control for firm size. However, we explore how our results change across firm size groups in detail in Section 5. Furthermore, since our growth variables are already expressed as differences (i.e. differences in size), we don't include a time-invariant firm-specific fixed effect in our preferred regression specification.

We estimate equation (2) via 'reduced-form' VARs, which do not impose any *a priori* causal

structure on the relationships between the variables.[8] These reduced-form VARs effectively correspond to a series of m individual OLS regressions (Stock and Watson (2001)).

One problem with OLS regressions in this particular case, however, is that the distribution of firm growth rates is typically exponentially distributed and has much heavier tails than the Gaussian. In this case, OLS and related estimators (such as Binder et al. (2005)) may provide unreliable results, and as argued in Bottazzi et al. (2008) we would prefer Least Absolute Deviation (LAD) estimation (also known as 'median regression').

Our intentions in this paper are to summarize the comovements of the growth series. We hesitate to try to establish any strong position on the underlying causality involved in the growth process. In theory, issues can be dealt with by using instrumental variables (IV) techniques, such as the 'System GMM' estimator (Blundell and Bond (1998)). The performance of instrumental variables estimators, however, depends on the quality of the instruments. If the instruments are effective then the estimates will be relatively precisely defined. If the instruments are weak, however, the point estimates may be strongly biased (even in large samples), and the confidence intervals surrounding the resulting estimates may also be downward-biased (Murray (2006)). This is likely to be the case in this study because it is difficult to find suitable instruments for firm growth rates because they are characteristically random and lack persistence (see the discussion in Geroski (2000) and Coad (2007e)). Lagged levels, for example, which are often used as instruments for differenced series in dynamic panel data IV GMM regressions, are of little use in our specific context. IV estimation of a panel VAR with weak instruments leads to imprecise estimates. In addition, Granger causality techniques cannot be relied upon in this context to help us establish the direction of causality between the VAR series. As a result, we merely focus on lead-lag associations that describe the comovements of the VAR series.

We also base our inference upon standard errors obtained using the computationally intensive 'bootstrapping' resampling technique (see Efron and Gong (1983) for an introduction).

4 Aggregate analysis

The regression results obtained from the OLS, Fixed-effects, and LAD estimators are presented in Tables 4, 5 and 6 respectively. It has been suggested that OLS is biased (upwards) in regressions of this kind where fixed effects are not included, whereas fixed-effects estimation is asymptotically biased (downwards) in panels where T is small (Bond (2002)). As a result,

[8] See however Coad (2007b) for a 'recursive' panel VAR of firm growth, which imposes more structure on the firm growth process. In this model, profits growth at time t depends on sales growth and employment growth at t, and where sales growth at t depends on employment growth at t. Employment growth at t, however, would not depend on any contemporaneous values of the other variables.

Table 4: OLS estimation of equation (2). Coefficients significant at the 5% level appear in bold ink.

w_t	β_{t-1}				β_{t-2}					
	Empl. growth	Sales growth	GOS growth	Prod. growth	Empl. growth	Sales growth	GOS growth	Prod. growth	R^2	obs
Empl. growth	0.0006	**0.0207**	**-0.0152**	**0.1119**					0.0254	25826
t-stat	0.04	6.20	-6.13	12.05						
Sales growth	**0.2485**	**-0.2275**	0.0078	**0.0756**					0.0477	25826
t-stat	7.50	-6.63	1.36	3.02						
GOS growth	**0.2813**	**0.1069**	**-0.3811**	**0.2749**					0.0927	25826
t-stat	5.83	5.74	-19.80	5.58						
Prod. growth	**-0.0515**	**0.0421**	**0.0312**	**-0.4126**					0.0977	25826
t-stat	4.12	5.99	6.77	-19.01						
Empl. growth	**-0.0372**	**0.0340**	**-0.0162**	**0.1118**	**0.0596**	**0.0157**	**-0.0113**	**0.0832**	0.0391	20460
t-stat	-2.14	7.14	-5.62	10.34	3.95	3.88	-4.19	8.05		
Sales growth	**0.2854**	**-0.2349**	-0.0018	**0.0871**	0.0425	**-0.0710**	0.0015	**-0.0084**	0.0455	20460
t-stat	7.35	-5.82	-0.33	3.15	1.23	-12.88	0.24	-2.45		
GOS growth	**0.3627**	**0.1816**	**-0.4812**	**0.3695**	0.0404	**0.0824**	**-0.2070**	0.0778	0.1288	20460
t-stat	6.76	8.05	-23.61	6.96	0.82	3.84	-10.43	1.44		
Prod. growth	**-0.0475**	**0.0651**	**0.0378**	**-0.4923**	**-0.0847**	**0.0244**	**0.0208**	**-0.2555**	0.1353	20460
t-stat	-2.26	8.23	6.86	-20.24	-5.37	3.48	4.80	-14.14		

Table 5: Fixed-effect estimation of equation (2). Coefficients significant at the 5% level appear in bold ink.

w_t	β_{t-1}				β_{t-2}					
	Empl. growth	Sales growth	GOS growth	Prod. growth	Empl. growth	Sales growth	GOS growth	Prod. growth	R^2	obs
Empl. growth	**-0.2205**	**0.0181**	**-0.0075**	**0.0698**					0.0105	25826
t-stat	-12.77	4.82	-3.01	7.55						
Sales growth	**0.1537**	**-0.3468**	0.0084	**0.0659**					0.0440	25826
t-stat	3.81	-9.13	0.10	2.38						
GOS growth	0.1048	**0.0995**	**-0.4242**	**0.1752**					0.0910	25826
t-stat	1.83	4.43	-19.96	3.15						
Prod. growth	**-0.0654**	**0.0461**	**0.0358**	**-0.5106**					0.0976	25826
t-stat	-2.99	5.48	6.64	-20.50						
Empl. growth	**-0.3228**	**0.0328**	**-0.0121**	**0.0843**	**-0.1905**	**0.0217**	-0.0028	**0.0460**	0.0092	20460
t-stat	-14.45	5.49	-4.25	7.99	-10.01	4.89	-1.00	4.40		
Sales growth	**0.1892**	**-0.4807**	0.0108	**0.0935**	**-0.1015**	**-0.1921**	**0.0230**	**-0.0718**	0.0375	20460
t-stat	3.25	-8.71	1.88	2.59	-2.27	-5.61	3.65	-2.27		
GOS growth	**0.1421**	**0.2141**	**-0.5809**	**0.2176**	**-0.1547**	**0.1163**	**-0.2720**	-0.0550	0.1243	20460
t-stat	2.27	7.94	-27.34	3.78	-2.67	4.80	-13.24	-0.92		
Prod. growth	**-0.0776**	**0.0846**	**0.0497**	**-0.6903**	**-0.0962**	**0.0390**	**0.0309**	**-0.4070**	0.1343	20460
t-stat	-3.11	7.94	8.28	-24.71	-4.87	4.52	5.91	-19.28		

Table 6: LAD estimation of equation (2). Coefficients significant at the 5% level appear in bold ink..

w_t	β_{t-1}				β_{t-2}					
	Empl. growth	Sales growth	GOS growth	Prod. growth	Empl. growth	Sales growth	GOS growth	Prod. growth	R^2	obs
Empl. growth	**0.0734**	**0.0123**	**-0.0103**	**0.0744**					0.0120	25826
t-stat	17.04	7.49	-9.43	20.85						
Sales growth	**0.1483**	**-0.0500**	-0.0029	**0.0295**					0.0038	25826
t-stat	13.81	-12.18	-1.08	3.32						
GOS growth	**0.2037**	**0.1205**	**-0.2884**	**0.2081**					0.0240	25826
t-stat	7.19	11.13	-40.3	8.86						
Prod. growth	-0.0051	**0.0278**	**0.0109**	**-0.2717**					0.0267	25826
t-stat	-0.53	7.61	4.51	-34.23						
Empl. growth	**0.0595**	**0.0224**	**-0.0107**	**0.0751**	**0.0665**	**0.0097**	**-0.0067**	**0.0495**	0.0195	20460
t-stat	11.96	10.6	-8.14	18.15	13.26	4.63	-4.82	10.43		
Sales growth	**0.1758**	**-0.0654**	-0.0051	**0.0311**	**0.0509**	**-0.0266**	-0.0032	0.0031	0.0055	20460
t-stat	13.72	-11.99	-1.51	2.91	3.94	-4.92	-0.9	-0.25		
GOS growth	**0.2791**	**0.1669**	**-0.3616**	**0.2537**	-0.0255	**0.0729**	**-0.1198**	**-0.0609**	0.0373	20460
t-stat	9.27	13.02	-45.32	10.13	-0.84	5.76	-14.18	-2.12		
Prod. growth	0.0029	**0.0387**	**0.0123**	**-0.3289**	**-0.0568**	**0.0138**	**0.0124**	**-0.1931**	0.0390	20460
t-stat	0.22	6.96	3.56	-30.2	-4.31	2.51	3.38	-15.44		

we present regression results for both OLS and fixed-effects regressions, even if our preferred specification is the LAD regression.

It is encouraging to observe that the results obtained from these estimators, and from the different regression specifications (one or two lags) are not too dissimilar. One major difference between the Gaussian estimators (OLS and FE) and LAD is that the magnitudes of the autocorrelation coefficients (along the 'diagonals') are much smaller using the LAD estimator. (This peculiar characteristic regarding estimation of the autocorrelation coefficient was observed by Bottazzi et al. (2008) and is explored in Coad (2007a).) We also note that the fixed-effects regressions yield fewer significant results than the OLS regressions, which in turn yield fewer significant results than the LAD regressions. The coefficients on the variables lagged twice are roughly speaking less significant than those on the first lag. It is also worth mentioning that whilst the growth of GOS seems to be slightly negatively associated with subsequent growth of sales and employment in the LAD results, these coefficients appear to be positive in the OLS and FE regressions (we are therefore cautious in our interpretations of this result). We base our interpretations mainly on the LAD results.

A first observation is that most of the series (except for employment growth) exhibit negative autocorrelation – this is shown along the diagonals of the coefficient matrices for the lags. This is in line with previous work. The autocorrelation coefficients for the growth of profits and of labour productivity display a particularly large negative sign. Whilst a substantial previous literature has emphasized the 'persistence of profits', the *growth* of profits has little persistence. This pronounced negative autocorrelation for profits and productivity growth may well be due to 'behavioural' factors whereby an increase (or decrease) in performance in one year may be followed by a 'slackening off' (or extra effort) of the workforce. Indeed, it may be that a period of successful achievement may be followed by a renegotiation of the organization's goals in the direction of a redistribution of the rents towards the employees, or the fostering of a more relaxed working environment.

Our results suggest that growth of a firm's employment is associated with previous growth of sales and of labour productivity. Sales growth and labour productivity growth have a relatively small positive effect, and the magnitude is comparable even at the second lag. Employment growth, however, appears to be relatively strongly associated with subsequent growth of sales and of profits. As could be expected, sales growth and productivity growth also appear to make a relatively large contribution to the subsequent growth of profits. Indeed, sales growth has a sizeable impact on profits growth even at the second lag.

We also observe that growth in labour productivity seems to be preceded by growth of sales. The coefficient is positive and statistically significant, but rather small in practical terms. Employment growth has no clear association with subsequent productivity growth after one year, although the association after two years is slightly negative.

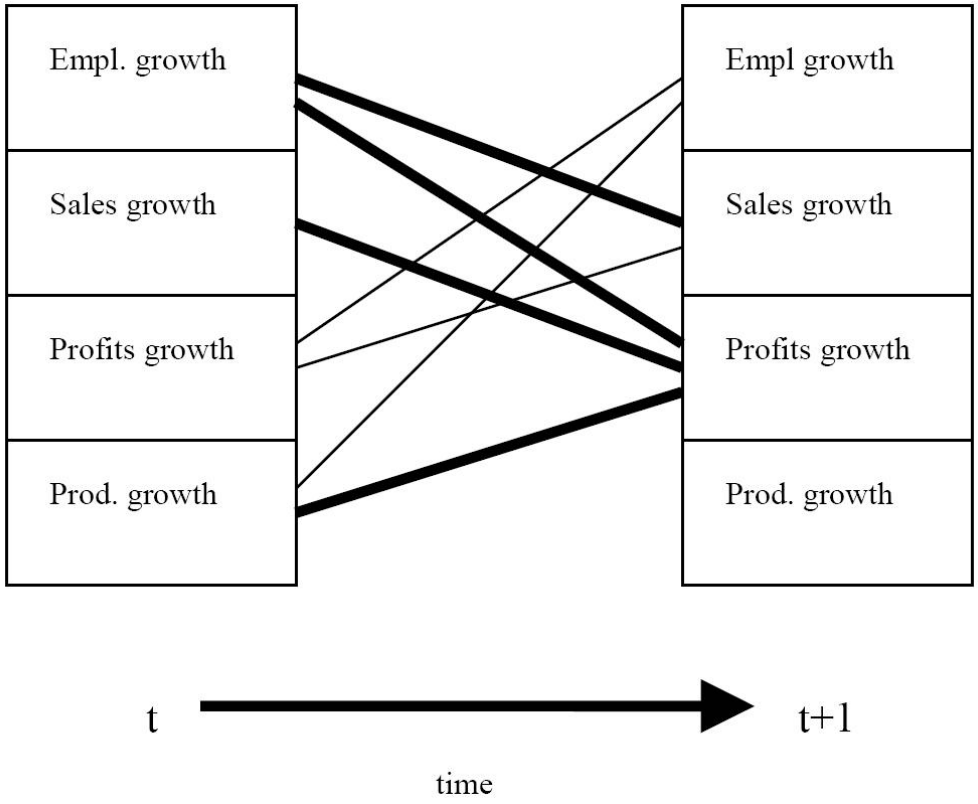

Figure 1: A stylized representation of the firm growth process, based on the estimates in Table 6. Thick lines represent 'strong' associations corresponding to coefficients greater than 0.10 in magnitude. Thin lines represent 'weak' associations corresponding to coefficients between 0.05 and 0.10 in magnitude. Autocorrelation coefficients are not considered in this figure.

In addition, it appears that growth of profits is associated with a relatively small subsequent growth in sales, and an even smaller growth of employment. Growth of profits may have a more persistent effect on employment growth than for sales growth, however. Growth of sales, on the other hand, is very strongly associated with subsequent growth of profits.

It is rather straightforward to interpret the magnitudes of the coefficients. If we observe that employment growth rate increases by 1 percentage point, then *ceteris paribus* we can expect sales growth to rise by about 0.176 percentage points in the following year. Similarly, a 1 percentage point increase in sales growth can be expected to be followed by a 0.022 percentage point increase in employment growth.[9] However, we warn against putting too much faith in specific point estimates at this preliminary stage. (For example, the likely existence of measurement error in the growth rates will have a slight downward influence on the coefficient estimates.)

Figure 1 provides a graphical representation of our results. This simplistic figure emphasizes how firm growth, broadly defined, is associated with subsequent growth of profits. Growth of profits, we could speculate, may be something of an 'absorbing state', providing little feedback by way of subsequent growth of employment, sales, or productivity. This vision of the firm growth process is in considerable contrast to widely-shared intuitions that firm growth is closely related to profitability, and the alternative vision of the growth process set forth in this paper certainly has important implications for our understanding of firm behavior.

5 Extended analysis

In the following section we explore the robustness of our results in a number of ways. First, we consider a simpler regression specification and investigate whether we obtain similar coefficient estimates when we exclude one of the VAR series (Section 5.1). We also investigate the robustness of our findings by repeating the analysis at a more disaggregated level. We disaggregate firms according to size (Section 5.2) and sector of activity (Section 5.3), as well as repeating our regressions for individual years (Section 5.4). We also explore potential asymmetries in the growth process between growing and shrinking firms (Section 5.5).

5.1 Sensitivity to specification

In Table 3 we observed that the highest contemporaneous correlations between the VAR series were between GOS growth and labour productivity growth. This high degree of multicollinearity may lead to excessively sensitive coefficient estimates. To explore this sensitivity, we repeat

[9]This latter result is apparently far more modest than results reported for a sample of Dutch manufacturing firms in (Brouwer et al., 1993, p. 156), who observe that a 1% increase in sales leads to a (statistically significant) 0.33% increase in employment.

Table 7: LAD estimation of equation (2) where m=3 and corresponds to the vector (Empl. growth(i,t), Sales growth (i,t), GOS growth (i,t))'. Coefficients significant at the 5% level appear in bold ink.

w_t	β_{t-1}			β_{t-2}				
	Empl. gr.	Sales gr.	GOS gr.	Empl. gr.	Sales gr.	GOS gr.	R^2	obs
Empl growth	**0.0250**	**0.0216**	**0.0056**				0.0064	25826
t-stat	6.92	13.92	7.41					
Sales growth	**0.1272**	**-0.0392**	0.0025				0.0036	25826
t-stat	13.34	-9.61	1.28					
GOS growth	**0.0927**	**0.1341**	**-0.2282**				0.0230	25826
t-stat	3.83	12.93	-45.39					
Empl growth	**0.0180**	**0.0350**	**0.0052**	**0.0428**	**0.0187**	**0.0046**	0.0138	20460
t-stat	4.03	16.43	5.36	9.74	8.94	4.67		
Sales growth	**0.1486**	**-0.0558**	0.0018	**0.0526**	**-0.0253**	-0.0037	0.0053	20460
t-stat	13.37	-10.53	0.73	4.82	-4.88	-1.50		
GOS growth	**0.0997**	**0.2022**	**-0.2891**	0.0350	**0.0719**	**-0.1299**	0.0355	20460
t-stat	3.68	15.66	-49.37	1.31	5.70	-21.78		

the analysis excluding either the productivity growth or the GOS growth variables, and we hope to obtain similar coefficient estimates to those obtained earlier. In a sense, we are trading off problems related to multicollinearity against the introduction of (an additional source of) omitted variable bias.[10] Table 7 presents the regression results when productivity growth is excluded, and Table 8 presents the results when GOS growth is excluded.

It is encouraging that we still find that employment growth is relatively strongly associated with subsequent growth of sales in all specifications, which in turn is relatively strongly associated with the growth of profits. Sales growth is also observed to have a small feedback effect on subsequent employment growth, of a similar magnitude to that found in Table 6. As before, we also observe no association between employment growth and subsequent productivity growth one year later, although a small negative association is detected with a two-year lag. Another small difference concerns the relationship between growth of profits and subsequent growth of employment or sales.[11]

5.2 Size disaggregation

Due care needs to be taken to deal with how growth dynamics vary with factors such as firm size. We cannot suppose that it will be meaningful to take a 'grand average' over a large sample of firms and assume a common structural specification. Coad (2007a) shows how the time scale of growth processes varies between small and large firms. For example,

[10]We cannot entirely dispel the hypothesis that there may be an omitted variable bias in our baseline regression model. Our gleaning of the economic literature, as well as an inspection of the available variables in our dataset, however, does not suggest any major candidates for omitted variables.

[11]This latter finding was also observed in Coad (2007c)'s analysis of French manufacturing firms.

Table 8: LAD estimation of equation (2) where m=3 and corresponds to the vector (Empl. growth(i,t), Sales growth (i,t), labour productivity growth (i,t))'. Coefficients significant at the 5% level appear in bold ink.

w_t	β_{t-1}			β_{t-2}				
	Empl. gr.	Sales gr.	Prod. gr.	Empl. gr.	Sales gr.	Prod. gr.	R^2	obs
Empl growth	**0.0569**	**0.0133**	**0.0484**				0.0108	25826
t-stat	14.88	8.44	19.86					
Sales growth	**0.1428**	**-0.0486**	**0.0222**				0.0038	25826
t-stat	14.66	-12.07	3.57					
Prod growth	0.0135	**0.0272**	**-0.2410**				0.0265	25826
t-stat	1.40	6.82	-39.14					
Empl growth	**0.0415**	**0.0208**	**0.0478**	**0.0587**	**0.0101**	**0.0319**	0.0181	20460
t-stat	9.18	10.01	16.67	13.11	4.89	10.06		
Sales growth	**0.1654**	**-0.0664**	**0.0192**	**0.0479**	**-0.0257**	-0.0106	0.0054	20460
t-stat	13.82	-12.07	2.53	4.03	-4.70	-1.25		
Prod growth	0.0201	**0.0413**	**-0.2979**	**-0.0433**	**0.0141**	**-0.1620**	0.0384	20460
t-stat	1.68	7.49	-39.17	-3.64	2.59	-19.29		

whilst small firms display significant negative autocorrelation in annual growth rates, larger firms experience positive autocorrelation which is consistent with the idea that they plan their growth projects over a longer time horizon. As a result, before we can feel confident about the robustness of our results, we should investigate the possible coexistence of different growth patterns for firms of different sizes.

We split our sample into 5 size groups, according to their sales in 1989, and the results are presented in Table 9. The task of sorting growing entities into size groups is not straightforward statistical task, however. In Table 12 in the Appendix, therefore, we use an alternative methodology for sorting the firms into size groups (i.e. according to mean number of employees 1989-1997).

Although similar patterns are observed in each of the size groups, we observe that the autocorrelation coefficients (along the diagonals) do seem to vary with firm size. Generally speaking, large firms tend to have smoother growth paths than small firms, as evidenced by the more positive autocorrelation coefficients.

We also observe that employment growth has less of an effect on subsequent productivity growth for larger firms, which is consistent with the idea that small firms have to struggle to reach the minimum efficient scale (MES), and until they reach the MES increases in employment will be associated with increases in productivity. This latter observation was also found in the case of French firms (Coad (2007c)).

Table 9: LAD estimation of equation (2) across different size groups. Firms sorted into size groups according to their initial size (sales in 1989). Group 1 contains the smallest firms. Standard errors (and hence t-statistics) obtained from using 500 bootstrap replications. Coefficients significant at the 5% level appear in bold ink.

w_t	β_{t-1}					
	Empl. gr.	Sales gr.	GOS gr.	Prod. growth	R^2	obs
Size group 1						
Empl growth	0.0169	0.0058	**-0.0084**	**0.0696**	0.0070	2988
t-stat	0.85	1.09	-2.23	3.23		
Sales growth	**0.1921**	-0.0630	-0.0061	0.0456	0.0049	2988
t-stat	4.13	-1.47	-0.75	1.09		
GOS growth	**0.3222**	0.0767	**-0.2808**	0.2082	0.0248	2988
t-stat	2.89	1.74	-6.27	1.54		
Prod growth	0.0476	0.0246	0.0111	**-0.2723**	0.0272	2988
t-stat	1.07	1.73	0.90	-5.48		
Size group 2						
Empl growth	0.0302	**0.0185**	**-0.0117**	**0.0916**	0.0139	3178
t-stat	1.20	2.21	-2.26	4.56		
Sales growth	**0.2269**	-0.0721	-0.0159	**0.1202**	0.0063	3178
t-stat	4.53	-1.60	-1.24	2.75		
GOS growth	**0.4338**	**0.2233**	**-0.3647**	**0.4008**	0.0295	3178
t-stat	3.57	3.16	-6.71	3.04		
Prod growth	**0.0830**	**0.0536**	-0.0011	**-0.2322**	0.0282	3178
t-stat	2.09	2.73	-0.12	-5.22		
Size group 3						
Empl growth	**0.0941**	**0.0166**	**-0.0162**	**0.0953**	0.0131	3456
t-stat	4.01	2.16	-2.77	4.99		
Sales growth	**0.3028**	**-0.1247**	-0.0129	**0.1332**	0.0109	3456
t-stat	5.23	-4.25	-1.36	3.20		
GOS growth	**0.3844**	**0.1370**	**-0.2996**	**0.2911**	0.0234	3456
t-stat	3.44	3.25	-5.68	2.46		
Prod growth	0.0146	**0.0475**	0.0049	**-0.2519**	0.0266	3456
t-stat	0.33	2.47	0.52	-6.05		
Size group 4						
Empl growth	**0.0891**	**0.0421**	**-0.0112**	**0.0595**	0.0250	3490
t-stat	4.89	4.49	-2.47	4.35		
Sales growth	**0.1694**	-0.0360	-0.0144	0.0527	0.0041	3490
t-stat	3.86	-1.20	-1.16	1.56		
GOS growth	-0.0188	**0.3090**	**-0.2386**	0.0341	0.0175	3490
t-stat	-0.12	3.68	-2.89	0.19		
Prod growth	-0.0647	**0.0492**	0.0120	**-0.2671**	0.0213	3490
t-stat	-1.57	2.43	0.91	-5.40		
Size group 5						
Empl growth	**0.1200**	**0.0236**	-0.0009	**0.0258**	0.0224	3302
t-stat	5.41	2.05	-0.18	1.96		
Sales growth	**0.0868**	-0.0077	0.0227	-0.0544	0.0048	3302
t-stat	2.29	-0.30	1.70	-1.86		
GOS growth	0.0897	**0.2187**	**-0.2877**	0.1586	0.0188	3302
t-stat	0.73	2.67	-3.96	1.33		
Prod growth	-0.0847	**0.0749**	0.0040	**-0.2255**	0.0158	3302
t-stat	-1.56	2.68	0.22	-4.52		

5.3 Sectoral disaggregation

One possibility that deserves investigation is that there may be a sector-specific element in the dynamics of firm growth. For example, the evolution of the market may be easier to foresee in some industries (with mature technologies, for example) than in others. Industries may also vary in relation to the importance of employment growth for the growth of output. We explore how our results vary across industries by loosely following Bottazzi et al. (2002), and comparing the results from four particular sectors: precision instruments, basic metals, machinery and equipment, and textiles. These sectors have been chosen to represent the different sectors of Pavitt's taxonomy of industries (Pavitt (1984)); that is, science-based industries, scale-intensive industries, specialized supply industries, and supplier-dominated industries respectively.[12]

The regression results are presented in Table 10. Our results emphasize a certain degree of heterogeneity between diverse sectors, as could be expected. For example, in the Precision Instruments and Machinery/Equipment sectors, employment growth seems to make a particularly large contribution to subsequent sales growth. In addition, it appears that sales growth has a relatively large influence on subsequent productivity growth, in the Machinery/Equipment and Textiles sectors. All in all, however, a similar structure for the firm growth process is evident even when we disaggregate across sectors.

5.4 Temporal disaggregation

It may well be the case that the processes of firm growth are not insensitive to the business cycle. To investigate this possibility, we repeat our analysis for individual years (i.e. the years 1991, 1993, 1995 and 1997). The results are presented in Table 11.

We do indeed observe that the regression results vary over time. Our results suggest that the association of employment growth with subsequent labour productivity growth is particularly unstable over the years. Labour productivity growth also has a time-varying association with growth of profits and growth of sales. These results might be because of differences in the contributions of small and large firms to the processes of job creation and destruction over the business cycle ((Davis et al., 1996, Chapter 5)). More work is needed to investigate this result more thoroughly, however.

[12]The sectors we study are NAF 33 (manufacturing of medical, precision and optical instruments, watches and clocks), NAF 27 (manufacturing of basic metals), NAF 29 (manufacturing of machinery and equipment, nec.) and NAF 17 (manufacturing of textiles). Note that we do not follow exactly the methodology in Bottazzi et al. (2002) because we consider only 2-digit sectors, for want of a suitable number of observations.

Table 10: LAD estimation of equation (2) across different industries. Standard errors (and hence t-statistics) obtained from using 1000 bootstrap replications. Results significant at the 5% level appear in bold ink.

w_t	β_{t-1}					
	Empl. gr.	Sales gr.	GOS gr.	Prod. growth	R^2	obs
ateco 17: Textiles						
Empl growth	**0.1055**	0.0105	-0.0139	**0.0885**	0.0182	1376
t-stat	3.58	1.74	-1.76	4.53		
Sales growth	0.0104	0.0975	-0.0029	-0.0477	0.0043	1376
t-stat	0.13	1.48	-0.19	-1.31		
GOS growth	0.1020	0.0310	**-0.2725**	0.1622	0.0248	1376
t-stat	0.77	0.88	-3.91	1.24		
Prod growth	-0.1035	0.0160	0.0083	**-0.2614**	0.0297	1376
t-stat	-1.50	1.11	0.47	-3.99		
ateco 27: Basic metals						
Empl growth	0.0686	**0.0494**	**-0.0171**	0.0324	0.0153	1107
t-stat	1.86	2.53	-2.52	1.53		
Sales growth	0.1746	-0.0334	-0.0196	-0.0398	0.0111	1107
t-stat	1.40	-0.44	-0.99	-0.47		
GOS growth	-0.2451	0.2122	-0.1706	-0.2917	0.0427	1107
t-stat	-1.06	1.74	-1.50	-1.19		
Prod growth	-0.0356	**0.0826**	0.0008	**-0.3087**	0.0457	1107
t-stat	-0.40	2.18	0.06	-5.20		
ateco 29: Machinery and equipment						
Empl growth	**0.1212**	0.0042	**-0.0158**	**0.0895**	0.0150	3898
t-stat	6.42	0.79	-4.01	5.53		
Sales growth	**0.3212**	**-0.1844**	-0.0230	**0.1114**	0.0175	3898
t-stat	6.50	-5.06	-1.88	2.73		
GOS growth	**0.2369**	**0.1168**	**-0.3110**	0.1549	0.0311	3898
t-stat	2.49	2.32	-8.51	1.95		
Prod growth	-0.0342	**0.0439**	0.0052	**-0.2852**	0.0302	3898
t-stat	-0.74	2.21	0.48	-5.96		
ateco 33: Precision instruments						
Empl growth	**0.1945**	0.0254	-0.0205	0.1136	0.0369	533
t-stat	3.14	1.42	-1.53	1.86		
Sales growth	**0.3050**	-0.0610	-0.0221	0.1202	0.0145	533
t-stat	3.30	-1.03	-0.94	1.38		
GOS growth	0.4685	0.1217	**-0.3177**	0.4290	0.0212	533
t-stat	1.61	0.97	-2.20	1.04		
Prod growth	0.0703	0.0462	-0.0168	-0.1248	0.0140	533
t-stat	0.67	1.03	-0.55	-0.98		

Table 11: LAD estimation of equation (2) for four different years: 1991, 1993, 1995 and 1997. Standard errors (and hence t-statistics) obtained from using 500 bootstrap replications. Results significant at the 5% level appear in bold ink.

w_t	β_{t-1}					
	Empl. gr.	Sales gr.	GOS gr.	Prod. growth	R^2	obs
1991						
Empl growth	0.0174	0.0062	-0.0001	0.0268	0.0022	2677
t-stat	1.29	1.00	-0.01	1.74		
Sales growth	**0.0884**	0.0012	0.0088	-0.0068	0.0023	2677
t-stat	2.02	0.05	0.84	-0.18		
GOS growth	**0.2277**	0.0590	**-0.1577**	0.1649	0.0092	2677
t-stat	2.69	1.07	-2.85	1.46		
Prod growth	**0.0926**	0.0151	-0.0070	**-0.1409**	0.0179	2677
t-stat	2.23	0.84	-0.48	-2.74		
1993						
Empl growth	**0.0976**	0.0029	**-0.0095**	**0.0841**	0.0107	2477
t-stat	4.12	0.49	-2.86	5.41		
Sales growth	**0.3354**	**-0.2068**	-0.0121	**0.1926**	0.0142	2477
t-stat	5.32	-3.61	-1.12	3.99		
GOS growth	**0.2633**	**0.1630**	**-0.2731**	0.2196	0.0273	2477
t-stat	2.27	2.94	-6.61	1.62		
Prod growth	0.0294	**0.0416**	-0.0128	**-0.1698**	0.0161	2477
t-stat	0.81	2.74	-1.35	-3.73		
1995						
Empl growth	**0.1690**	**0.0327**	**-0.0237**	**0.1229**	0.0325	4626
t-stat	6.93	2.72	-6.27	-4.78		
Sales growth	**0.2483**	0.0130	**-0.0236**	**0.1625**	0.0119	4626
t-stat	7.43	0.62	-2.93	4.92		
GOS growth	**0.4176**	**0.1157**	**-0.2942**	**0.4874**	0.0175	4626
t-stat	3.70	2.21	-6.15	3.67		
Prod growth	0.0180	0.0252	-0.0116	**-0.0859**	0.0070	4626
t-stat	0.50	1.63	-1.59	-2.45		
1997						
Empl growth	0.0177	0.0090	-0.0039	**0.0422**	0.0036	4418
t-stat	0.83	1.64	-0.90	3.21		
Sales growth	**0.0835**	**-0.0904**	-0.0044	0.0053	0.0068	4418
t-stat	2.74	-3.18	-0.63	0.33		
GOS growth	**0.3854**	**0.1290**	**-0.4529**	**0.2664**	0.0625	4418
t-stat	4.10	3.75	-10.34	3.23		
Prod growth	**-0.0911**	**0.0322**	**0.0615**	**-0.5656**	0.0954	4418
t-stat	-2.18	3.40	5.20	-12.94		

5.5 Asymmetric effects for growing or shrinking firms

Quantile autoregressions to investigate asymmetric effects over the growth rate distribution. Intuitively, quantile regression is a weighted regression that estimates the regression equation at various points of the conditional growth rate distribution (conditional on the explanatory variables). Quantile regression is thus a useful technique for investigating differential effects on growth at various points of the growth rate distribution. For example, in the case of employment growth, it may be relatively easy for firms to hire new employees while firing costs may limit their ability to lay workers off, which would be a source of asymmetries between firms that undergo employment growth as opposed to employment decline. In this section, we explore differential effects of the explanatory variables over the growth rate distribution. To do this, we perform quantile regressions, which are able to describe variation in the regression coefficient over the conditional employment growth quantiles. (For an introduction to quantile regression, see Koenker and Hallock (2001); see also Koenker and Xiao (2006) for the case of quantile autoregression.

Figure 2, as well as Tables 13, 14, 15, 16 in the Appendix, present the quantile regression coefficient estimates. Roughly speaking, the lower quantiles (closer to 0) represent firms with negative growth rates, whilst the upper quantiles (closer to 1) represent firms with positive growth. The 50% quantile regression corresponds to a median regression.

In this section, we are most interested in differential effects across the quantiles of the growth rate distribution (i.e. those lines that are not 'flat' across the conditional growth rate distribution quantiles). Three points in particular seem worth emphasizing. First, we observe an inverse-U shaped autocorrelation profile across the quantiles, for employment growth, sales growth and productivity growth. These results suggest that forces of negative autocorrelation are particularly strong for those firms experiencing extreme growth events (fast growth or decline) in the previous year. If a firm has fast growth in any one year, it is quite unlikely to repeat this performance in the following year. Second, for firms experiencing rapid decline in sales or profits, these firms would have done better to have hired new workers in the previous period. Thus, taking on employees leads to stability for those firms that later on experience sharp negative growth. This is reminiscent of results in Reichstein et al. (2006), who find that a large size tends to slow down firm growth for the fastest growing firms but can attenuate the pace of decline in rapidly shrinking firms. Third, although productivity growth is positively associated with subsequent growth of profits, this relationship is less clear for firms experiencing rapid decline in profits. It is also interesting to observe that employment growth is positively associated with subsequent profits growth for firms experiencing declining profits, but the relationship is less clear (and perhaps negative) for firms experiencing profit growth (this was also observed in Coad (2007c) on French data).

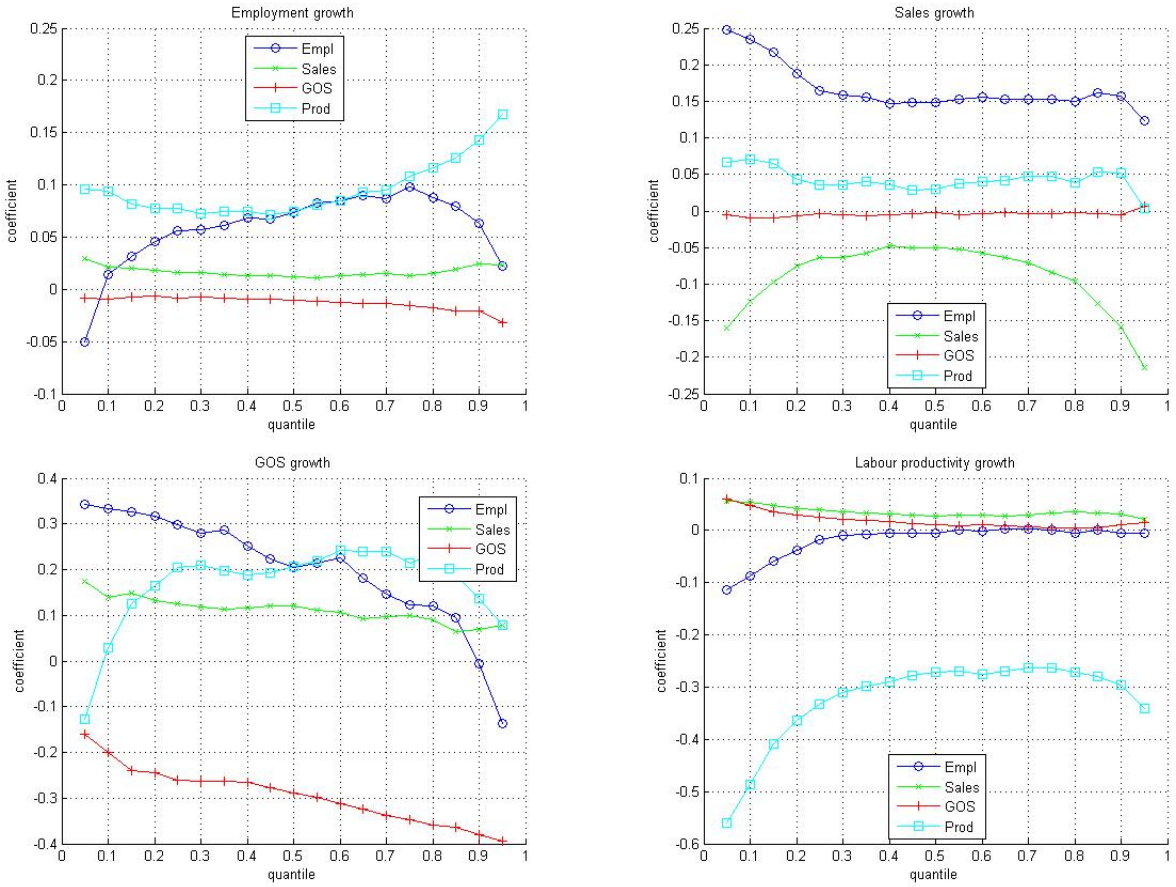

Figure 2: Summary of the quantile autoregression analysis.

6 Conclusion

This paper analyzes growth patterns of manufacturing firms using reduced-form panel vector autoregressions. While the previous literature on firm growth attempts to explain growth rates using variables in levels, the approach taken here is describe the dynamic processes of firm growth, focusing in particular on employment growth, sales growth, growth of profits and labour productivity growth, and in particular the complex interactions between these variables.

Our analysis yields several interesting results, that are comparable to those obtained using data on US and French manufacturing firms. The general description that emerges is that employment growth precedes sales growth and growth of profits, and that sales growth is also associated with subsequent profits growth. There appears to be little feedback of either sales or profits on employment growth, however. There is no clear association of employment growth with subsequent changes in labour productivity, although at the second lag there is a small negative association. Productivity growth, however, is positively associated with subsequent growth of employment and sales.

Our analysis focused on descriptions of lead-lag associations between different dimensions of firm growth and performance. Although we do not claim to have established any clear direction of causality between these variables, our results are not consistent with two dominant theories of firm growth. First, the 'replicator dynamics' model, frequently found in neo-Schumpeterian evolutionary models, supposes that retained profits are the main source of firm growth. In this vein, we should expect profitable firms to grow whilst struggling firms would lose market share. Second, and not altogether unrelated, the 'accelerator' models of firm investment suppose that growth of sales leads to a subsequent reinvesting in the firm, which would thus result in employment growth. Our results show that growth of sales and profits are not strongly associated with subsequent employment growth, however, which casts doubt on these theories. Instead, our results are consistent with the view that employment growth is the key driver of firm expansion (broadly defined), and that profits, once made, are not reinvested.

Where, then, does the initial shock to employment growth come from? The extant literature on firm growth, in the Gibrat's Law tradition, would suggest that we consider this merely as an exogenous stochastic shock. However, the origins of employment growth certainly deserve more investigation. Proponents of the 'rationalist' school might suggest that employment growth is caused by expectations of profits several years into the future. Taken to the extreme, this 'rationalist' view would suggest that employment growth is *caused* by subsequent growth of profits (which would have been correctly anticipated years in advance). More behavioural theories of the firm, however, resting on principles such as 'managerialist expansion' or 'bounded rationality', would downplay the role of accurate anticipations of fu-

ture profits on firm growth. Our results do not allow us to comment on the possibility that it is the expectations of future profits that lead firms to take on new employees. However, our results are at odds with the hypothesis that profitable firms use their profits on expansion, once these profits have been acquired.

Some other key results are as follows. Employment growth is more strongly associated with labour productivity in the case of small firms, presumably because these firms have to grow to reach their Minimum Efficient Scale, above which they enjoy economies of scale. Employment growth can also be a source of stability, which is particularly valuable for firms experiencing sharp declines in sales or profits in following years.

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Appendix

Table 12: LAD estimation of equation (2) across different size groups. Firms sorted into size groups according to their mean size (average number of employees 1989-1997). Group 1 contains the smallest firms. Standard errors (and hence t-statistics) obtained from using 500 bootstrap replications.

w_t	β_{t-1}					
	Empl. gr.	Sales gr.	GOS gr.	Prod. growth	R^2	obs
Size group 1						
Empl growth	**-0.0623**	0.0172	**-0.0143**	**0.0678**	0.0098	2905
t-stat	-2.21	1.53	-2.61	3.33		
Sales growth	0.0654	**-0.0714**	0.0154	-0.0397	0.0041	2905
t-stat	1.22	-2.14	1.67	-1.18		
GOS growth	0.1062	**0.2144**	**-0.2898**	0.0593	0.0282	2905
t-stat	0.94	4.70	-6.25	0.48		
Prod growth	0.0150	**0.0881**	0.0175	**-0.3210**	0.0296	2905
t-stat	0.31	3.69	1.49	-6.69		
Size group 2						
Empl growth	0.0007	0.0234	-0.0072	**0.0513**	0.0079	2954
t-stat	0.02	1.95	-1.06	2.33		
Sales growth	**0.1789**	-0.0506	-0.0083	0.0599	0.0052	2954
t-stat	4.33	-1.62	-0.96	1.62		
GOS growth	0.2769	**0.2165**	**-0.3333**	0.2165	0.0316	2954
t-stat	1.85	3.97	-5.02	1.38		
Prod growth	**0.1082**	**0.0678**	0.0028	**-0.2645**	0.0401	2954
t-stat	2.39	5.66	0.33	-7.86		
Size group 3						
Empl growth	**0.0911**	**0.0214**	-0.0099	**0.0905**	0.0182	2926
t-stat	4.08	2.31	-1.36	4.21		
Sales growth	**0.1914**	**-0.1045**	0.0026	0.0939	0.0072	2926
t-stat	2.73	-2.22	0.16	1.61		
GOS growth	**0.3482**	**0.1467**	**-0.3128**	**0.3141**	0.0227	2926
t-stat	2.44	2.11	-4.79	1.97		
Prod growth	-0.0039	0.0203	0.0152	**-0.2589**	0.0217	2926
t-stat	-0.10	1.00	1.38	-4.64		
Size group 4						
Empl growth	**0.1605**	**0.0195**	**-0.0111**	**0.0766**	0.0286	2947
t-stat	6.46	2.21	-2.23	3.99		
Sales growth	**0.2563**	**-0.0678**	-0.0123	**0.1080**	0.0092	2947
t-stat	5.28	-2.09	-1.11	3.02		
GOS growth	0.2309	**0.1799**	**-0.2802**	0.2847	0.0191	2947
t-stat	1.70	3.73	-3.96	1.84		
Prod growth	-0.0537	**0.0484**	0.0061	**-0.2218**	0.0185	2947
t-stat	-1.31	2.24	0.41	-5.00		
Size group 5						
Empl growth	**0.0770**	**0.0093**	**-0.0082**	**0.0694**	0.0108	14094
t-stat	8.78	4.03	-3.99	9.88		
Sales growth	**0.1256**	**-0.0384**	-0.0040	0.0159	0.0029	14094
t-stat	5.53	-2.06	-0.89	1.05		
GOS growth	**0.1677**	**0.0694**	**-0.2792**	**0.1834**	0.0243	14094
t-stat	3.41	3.19	-11.75	3.60		
Prod growth	-0.0263	**0.0170**	**0.0111**	**-0.2793**	0.0288	14094
t-stat	-1.29	3.31	2.06	-14.09		

Table 13: Quantile autoregression coefficients with employment growth as the dependent variable. Standard errors (and hence t-statistics) calculated using 100 bootstrap replications. Results significant at the 5% level appear in bold ink.

Quantile		Empl growth	Sales growth	GOS growth	Prod growth	R2	obs
q(0.05)	Empl growth	**-0.0501**	**0.0291**	**-0.0088**	**0.0961**	0.0171	25826
	t-stat	-2.52	5.28	-2.09	7.92		
q(0.10)	Empl growth	0.0145	**0.0217**	**-0.0097**	**0.0941**	0.0139	25826
	t-stat	1.2	4.43	-3.49	9.37		
q(0.15)	Empl growth	**0.0311**	**0.0201**	**-0.0072**	**0.0817**	0.0136	25826
	t-stat	2.72	4.61	-2.61	8.11		
q(0.20)	Empl growth	**0.0456**	**0.0183**	**-0.0067**	**0.0780**	0.0134	25826
	t-stat	4.43	7.23	-2.54	9.77		
q(0.25)	Empl growth	**0.0559**	**0.0157**	**-0.0081**	**0.0777**	0.0129	25826
	t-stat	7.36	5.72	-3.87	10.64		
q(0.30)	Empl growth	**0.0571**	**0.0157**	**-0.0073**	**0.0721**	0.0129	25826
	t-stat	6.85	4.81	-3.8	9.87		
q(0.35)	Empl growth	**0.0613**	**0.0146**	**-0.0089**	**0.0742**	0.0124	25826
	t-stat	8.41	4.21	-5.44	11.3		
q(0.40)	Empl growth	**0.0681**	**0.0133**	**-0.0098**	**0.0750**	0.0131	25826
	t-stat	9.58	5.19	-5.28	12.07		
q(0.45)	Empl growth	**0.0678**	**0.0132**	**-0.0099**	**0.0713**	0.0098	25826
	t-stat	11.03	5.27	-5	10.89		
q(0.50)	Empl growth	**0.0734**	**0.0123**	**-0.0103**	**0.0744**	0.0120	25826
	t-stat	11.19	4.98	-5.66	13.02		
q(0.55)	Empl growth	**0.0829**	**0.0113**	**-0.0111**	**0.0809**	0.0135	25826
	t-stat	12.1	4.65	-7.66	13.53		
q(0.60)	Empl growth	**0.0852**	**0.0126**	**-0.0120**	**0.0852**	0.0136	25826
	t-stat	9.83	5.22	-6.74	14.65		
q(0.65)	Empl growth	**0.0895**	**0.0140**	**-0.0135**	**0.0933**	0.0137	25826
	t-stat	10.47	6.38	-8.13	15.25		
q(0.70)	Empl growth	**0.0867**	**0.0154**	**-0.0139**	**0.0949**	0.0137	25826
	t-stat	8.9	6.82	-6.95	11.7		
q(0.75)	Empl growth	**0.0976**	**0.0134**	**-0.0158**	**0.1087**	0.0146	25826
	t-stat	8.95	4.64	-8.03	16.94		
q(0.80)	Empl growth	**0.0874**	**0.0150**	**-0.0181**	**0.1161**	0.0156	25826
	t-stat	7.7	5.59	-8.85	13.34		
q(0.85)	Empl growth	**0.0800**	**0.0197**	**-0.0204**	**0.1257**	0.0161	25826
	t-stat	7.03	6.83	-6.6	11.12		
q(0.90)	Empl growth	**0.0629**	**0.0247**	**-0.0207**	**0.1431**	0.0172	25826
	t-stat	4.11	6.64	-6.44	12.73		
q(0.95)	Empl growth	0.0224	**0.0236**	**-0.0320**	**0.1681**	0.0187	25826
	t-stat	0.81	3.65	-5.3	8.85		

Table 14: Quantile autoregression coefficients with sales growth as the dependent variable. Standard errors (and hence t-statistics) calculated using 100 bootstrap replications. Results significant at the 5% level appear in bold ink.

Quantile		Empl growth	Sales growth	GOS growth	Prod growth	R2	obs
q(0.05)	Sales growth	**0.2471**	**-0.1600**	-0.0047	0.0659	0.0118	25826
	t-stat	6.53	-5.12	-0.49	1.75		
q(0.10)	Sales growth	**0.2346**	**-0.1229**	-0.0094	**0.0712**	0.0089	25826
	t-stat	7.64	-5.41	-1.45	3.47		
q(0.15)	Sales growth	**0.2174**	**-0.0969**	-0.0093	**0.0656**	0.0074	25826
	t-stat	11.58	-5.07	-1.82	3.99		
q(0.20)	Sales growth	**0.1881**	**-0.0753**	-0.0059	**0.0424**	0.0059	25826
	t-stat	9.68	-4.21	-1.54	2.77		
q(0.25)	Sales growth	**0.1645**	**-0.0639**	-0.0036	**0.0355**	0.0049	25826
	t-stat	10.39	-4.25	-1.19	2.49		
q(0.30)	Sales growth	**0.1582**	**-0.0632**	-0.0044	**0.0361**	0.0044	25826
	t-stat	8.69	-4.05	-1.00	2.53		
q(0.35)	Sales growth	**0.1555**	**-0.0581**	-0.0066	**0.0403**	0.0041	25826
	t-stat	9.14	-4.34	-1.46	3.18		
q(0.40)	Sales growth	**0.1474**	**-0.0480**	-0.0056	**0.0361**	0.0038	25826
	t-stat	9.62	-3.61	-1.71	3.27		
q(0.45)	Sales growth	**0.1479**	**-0.0506**	-0.0036	**0.0286**	0.0037	25826
	t-stat	8.63	-3.75	-1.09	2.42		
q(0.50)	Sales growth	**0.1483**	**-0.0500**	-0.0029	**0.0295**	0.0038	25826
	t-stat	8.51	-3.88	-0.98	2.20		
q(0.55)	Sales growth	**0.1530**	**-0.0522**	-0.0046	**0.0380**	0.0039	25826
	t-stat	8.64	-3.87	-1.16	2.95		
q(0.60)	Sales growth	**0.1559**	**-0.0573**	-0.0039	**0.0402**	0.0041	25826
	t-stat	8.88	-4.79	-1.24	3.18		
q(0.65)	Sales growth	**0.1529**	**-0.0632**	-0.0025	**0.0411**	0.0043	25826
	t-stat	7.85	-4.81	-0.56	2.65		
q(0.70)	Sales growth	**0.1535**	**-0.0708**	-0.0032	**0.0470**	0.0048	25826
	t-stat	9.70	-5.83	-1.05	3.44		
q(0.75)	Sales growth	**0.1525**	**-0.0845**	-0.0030	**0.0481**	0.0054	25826
	t-stat	7.84	-5.65	-0.81	3.10		
q(0.80)	Sales growth	**0.1492**	**-0.0963**	-0.0024	**0.0382**	0.0063	25826
	t-stat	6.68	-5.03	-0.59	2.34		
q(0.85)	Sales growth	**0.1613**	**-0.1260**	-0.0035	**0.0537**	0.0084	25826
	t-stat	5.13	-4.78	-0.61	2.39		
q(0.90)	Sales growth	**0.1578**	**-0.1593**	-0.0051	0.0526	0.0135	25826
	t-stat	4.60	-5.24	-0.72	1.75		
q(0.95)	Sales growth	**0.1241**	**-0.2139**	0.0064	0.0039	0.0265	25826
	t-stat	2.66	-6.26	0.68	0.09		

Table 15: Quantile autoregression coefficients with GOS growth as the dependent variable. Standard errors (and hence t-statistics) calculated using 100 bootstrap replications. Results significant at the 5% level appear in bold ink.

Quantile		Empl growth	Sales growth	GOS growth	Prod growth	R2	obs
q(0.05)	GOS growth	**0.3417**	**0.1731**	**-0.1601**	-0.1273	0.0108	25826
	t-stat	3.33	3.29	-3.65	-0.93		
q(0.10)	GOS growth	**0.3337**	**0.1389**	**-0.2011**	0.0301	0.0121	25826
	t-stat	4.72	4.09	-7.72	0.43		
q(0.15)	GOS growth	**0.3254**	**0.1480**	**-0.2399**	0.1241	0.0132	25826
	t-stat	4.95	6.33	-8.94	1.90		
q(0.20)	GOS growth	**0.3159**	**0.1325**	**-0.2456**	**0.1660**	0.0138	25826
	t-stat	4.90	5.34	-9.37	2.49		
q(0.25)	GOS growth	**0.2982**	**0.1263**	**-0.2604**	**0.2050**	0.0144	25826
	t-stat	6.64	5.89	-10.63	4.02		
q(0.30)	GOS growth	**0.2800**	**0.1170**	**-0.2635**	**0.2104**	0.0158	25826
	t-stat	6.75	6.14	-14.26	5.19		
q(0.35)	GOS growth	**0.2868**	**0.1127**	**-0.2632**	**0.1970**	0.0178	25826
	t-stat	7.81	6.11	-15.91	5.80		
q(0.40)	GOS growth	**0.2525**	**0.1158**	**-0.2655**	**0.1887**	0.0198	25826
	t-stat	7.59	6.67	-17.75	4.52		
q(0.45)	GOS growth	**0.2225**	**0.1205**	**-0.2773**	**0.1934**	0.0218	25826
	t-stat	6.34	7.11	-16.33	4.46		
q(0.50)	GOS growth	**0.2037**	**0.1205**	**-0.2884**	**0.2081**	0.0240	25826
	t-stat	5.04	8.34	-16.37	4.57		
q(0.55)	GOS growth	**0.2138**	**0.1122**	**-0.2983**	**0.2195**	0.0266	25826
	t-stat	5.55	7.52	-16.76	4.91		
q(0.60)	GOS growth	**0.2264**	**0.1064**	**-0.3122**	**0.2411**	0.0299	25826
	t-stat	6.03	6.81	-16.78	6.12		
q(0.65)	GOS growth	**0.1814**	**0.0932**	**-0.3232**	**0.2408**	0.0336	25826
	t-stat	4.77	5.34	-15.86	5.58		
q(0.70)	GOS growth	**0.1461**	**0.0976**	**-0.3389**	**0.2406**	0.0383	25826
	t-stat	3.35	5.91	-17.30	5.74		
q(0.75)	GOS growth	**0.1228**	**0.0998**	**-0.3471**	**0.2136**	0.0450	25826
	t-stat	2.78	4.75	-18.46	5.07		
q(0.80)	GOS growth	**0.1209**	**0.0893**	**-0.3595**	**0.2322**	0.0535	25826
	t-stat	3.12	4.67	-19.36	5.15		
q(0.85)	GOS growth	0.0955	**0.0636**	**-0.3646**	**0.1874**	0.0652	25826
	t-stat	1.80	2.92	-16.88	2.92		
q(0.90)	GOS growth	-0.0061	**0.0697**	**-0.3791**	**0.1360**	0.0843	25826
	t-stat	-0.10	3.23	-15.31	2.07		
q(0.95)	GOS growth	-0.1361	**0.0775**	**-0.3951**	0.0778	0.1191	25826
	t-stat	-1.51	2.57	-16.26	0.95		

Table 16: Quantile autoregression coefficients with labour productivity growth as the dependent variable. Standard errors (and hence t-statistics) calculated using 100 bootstrap replications. Results significant at the 5% level appear in bold ink.

Quantile		Empl growth	Sales growth	GOS growth	Prod growth	R2	obs
q(0.05)	Prod growth	**-0.1130**	**0.0559**	**0.0610**	**-0.5602**	0.0809	25826
	t-stat	-2.85	5.49	7.56	-18.24		
q(0.10)	Prod growth	**-0.0866**	**0.0535**	**0.0484**	**-0.4854**	0.0551	25826
	t-stat	-2.77	6.49	5.88	-15.89		
q(0.15)	Prod growth	**-0.0595**	**0.0486**	**0.0349**	**-0.4095**	0.0435	25826
	t-stat	-2.53	6.23	4.24	-12.87		
q(0.20)	Prod growth	-0.0378	**0.0414**	**0.0287**	**-0.3639**	0.0365	25826
	t-stat	-1.84	5.62	4.42	-14.98		
q(0.25)	Prod growth	-0.0169	**0.0404**	**0.0248**	**-0.3325**	0.0325	25826
	t-stat	-1.07	5.52	5.14	-15.43		
q(0.30)	Prod growth	-0.0100	**0.0346**	**0.0210**	**-0.3100**	0.0308	25826
	t-stat	-0.57	5.08	3.86	-15.77		
q(0.35)	Prod growth	-0.0072	**0.0325**	**0.0188**	**-0.2972**	0.0291	25826
	t-stat	-0.37	4.73	3.55	-14.01		
q(0.40)	Prod growth	-0.0048	**0.0309**	**0.0164**	**-0.2906**	0.0278	25826
	t-stat	-0.32	5.73	3.53	-15.66		
q(0.45)	Prod growth	-0.0051	**0.0289**	**0.0121**	**-0.2774**	0.0269	25826
	t-stat	-0.34	4.90	2.73	-15.40		
q(0.50)	Prod growth	-0.0051	**0.0278**	**0.0109**	**-0.2717**	0.0267	25826
	t-stat	-0.39	4.98	2.73	-17.90		
q(0.55)	Prod growth	0.0012	**0.0288**	**0.0097**	**-0.2694**	0.0269	25826
	t-stat	0.09	5.02	2.71	-20.11		
q(0.60)	Prod growth	-0.0011	**0.0293**	**0.0106**	**-0.2758**	0.0269	25826
	t-stat	-0.07	5.35	2.75	-15.85		
q(0.65)	Prod growth	0.0032	**0.0283**	**0.0080**	**-0.2685**	0.0270	25826
	t-stat	0.19	5.09	2.05	-15.54		
q(0.70)	Prod growth	0.0020	**0.0302**	**0.0070**	**-0.2638**	0.0276	25826
	t-stat	0.13	4.84	1.96	-16.83		
q(0.75)	Prod growth	0.0013	**0.0332**	0.0052	**-0.2629**	0.0289	25826
	t-stat	0.09	5.08	1.27	-17.58		
q(0.80)	Prod growth	-0.0051	**0.0349**	0.0054	**-0.2714**	0.0305	25826
	t-stat	-0.28	5.18	1.72	-18.15		
q(0.85)	Prod growth	0.0011	**0.0341**	0.0056	**-0.2804**	0.0330	25826
	t-stat	0.06	5.56	1.28	-16.10		
q(0.90)	Prod growth	-0.0062	**0.0309**	**0.0108**	**-0.2956**	0.0350	25826
	t-stat	-0.28	5.12	2.01	-11.55		
q(0.95)	Prod growth	-0.0056	**0.0214**	0.0142	**-0.3404**	0.0411	25826
	t-stat	-0.21	1.96	1.94	-10.90		