Documents de Travail du
Centre d'Economie de la Sorbonne

CES Working Papers

Exploring the « mechanics » of firm growth : evidence from a short-panel VAR

Alex COAD

2007.37

CENTRE NATIONAL
DE LA RECHERCHE
SCIENTIFIQUE

Maison des Sciences Économiques, 106-112 boulevard de L'Hôpital, 75647 Paris Cedex 13
http://ces.univ-paris1.fr/cesdp/CES-docs.htm
ISSN : 1955-611X

Exploring the 'mechanics' of firm growth: evidence from a short-panel VAR*

Alex Coad [a] [b] [†]

a Max Planck Institute of Economics, Jena, Germany

b Centre d'Economie de la Sorbonne, Equipe MATISSE, Univ. Paris 1 – CNRS

July 9, 2007

Abstract

This paper offers many new insights into the processes of firm growth by applying a vector autoregression (VAR) model to longitudinal panel data on French manufacturing firms. We observe the co-evolution of key variables such as growth of employment, sales, gross operating surplus, and labour productivity growth. Preliminary results suggest that employment growth is succeeded by the growth of sales, which in turn is followed by growth of profits. Generally speaking, however, growth of profits is not followed by much employment growth or sales growth.

Une investigation des processus de croissance des entreprises

Résumé: Cet article offre un certain nombre de résultats concernant les processus de croissance des firmes, en appliquant un modèle VAR (Vector Autoregression) à des données longitudinales sur des entreprises manufacturières francaises. Nous observons la co-evolution de variables-clés telles que la croissance d'emplois, du chiffre d'affaires, de l'excédent brut d'exploitation ('profits'), et de la productivité de la main-d'oeuvre. Nos résultats suggèrent que la croissance d'emplois est suivie par la croissance du chiffre d'affaires, qui est ensuite suivie par la croissance des profits. Il semblerait toutefois que la croissance des profits n'est pas suivie par la croissance d'emplois ou du chiffre d'affaires.

JEL codes: L25, L20

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

Mots clés: Croissance des firmes, Panel VAR, Création d'emplois, Economie industrielle, croissance de productivité.

*I thank Thomas Brenner, Tom Broekel, Guido Buenstorf, Andreas Chai, Christian Cordes, Giovanni Dosi, Corinna Manig, Dick Nelson, Jason Potts, Kerstin Press, Rekha Rao, Andrea Roventini, Erik Stam, Vera Troeger, Marco Valente, Karl Wennberg, Claudia Werker, Ulrich Witt, participants at the EMAEE 2007 conference in Manchester, and seminar participants at the Max Planck Institute, Jena, for many useful comments. I also thank Michael Binder for sending the code for the Binder-Hsiao-Pesaran (2005) short-panel VAR estimator. The usual caveat applies.

[†] *Corresponding Author*: Alex Coad, Max Planck Institute of Economics, Evolutionary Economics Group, Kahlaische Strasse 10, D-07745 Jena, Germany. *Phone*: +49 3641 686822. *Fax*: +49 3641 686868. *E-mail*: coad@econ.mpg.de

1 Introduction

The literature on firm growth, at present, consists mainly of empirical investigations along the framework of Gibrat's Law, where firm growth features as the dependent variable and firm size is an independent variable. In such regressions, different indicators of firm growth (e.g. sales growth or employment growth) are considered almost interchangeably as proxies for the same underlying phenomenon (i.e. firm growth). There are also many other 'augmented' versions of Gibrat's law, in which other characteristics of the firm at time $(t-1)$ are included in the regression to explain the firm's growth from $(t-1:t)$ (for an extensive survey of the literature on firm growth, see Coad (2007)). Regressions of this kind have had limited success, however, because the explanatory power of these regressions is typically very low and the characteristics (in *levels*) of firms at a point in time (t) seem to have limited influence on the *rate of change* of firm size. Geroski has thus said in his despair: "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).

The empirical framework presented here is admittedly rather simple but, we argue, has the potential of shedding light on what happens inside growing firms. The approach we take is quite different to conventional empirical analysis of firm growth. Whilst sales, employment and profits are usually taken as alternative proxies for firm growth, we consider each of these indicators to be essentially different, each yielding unique information on different facets of firm growth. We therefore view firm growth as a multidimensional phenomenon. By considering the coevolution of these series, we can improve our understanding of the processes of firm growth. Implicit in our model is the idea that the growth of profits is not just a final outcome for firms but also as an input, because it provides firms with the means for expansion. Furthermore, employment growth can be seen as an input (in the production process) but also as an output if, for example, the policy maker is interested in the generation of new jobs. We suggest that this conception of the growing firm as a dynamic co-evolving system of interdependent variables is best described in the context of a panel vector autoregression (VAR) model.

Theoretical considerations Whilst many theoretical propositions about firm growth have been made, these have largely escaped empirical investigation. For example, it has long been supposed that the evolutionary principle of 'growth of the fitter' should apply to firms, such that the more productive or profitable firms should grow and the least productive or profitable should shrink and exit (see, for example, Alchian (1950), Friedman (1953) and Nelson and Winter (1982)). Many (evolutionary) economists would probably accept this idea without much thought. However, a growing empirical literature casts doubt on the relevance of these theoretical assertions. Recent work on productivity dynamics suggests that, if anything, there appears to be a mild negative relationship between productivity and firm growth, with relatively low productivity firms growing more. Similarly, (scant) evidence suggests that profits do not appear to lead to higher firm growth (see Coad (2005) and Bottazzi et al. (2006), and for a review of the empirical literature on the influence of productivity and profitability on firm growth, see Dosi (2007) and Coad (2007)).

Another topic that we feel is under-developed in the current literature is our understanding of the microfoundations of employment growth decisions (i.e. at the firm level). For instance, we could expect that the benefits of employment growth on profits may not be manifest immediately if it takes time for firms to adequately train new employees. Instead, new employees and new positions in the organization may make their most significant contribution to firm profitability only after a certain time lag. It is also of interest to investigate the elasticity of employment growth to profit growth. Do profitable firms create new jobs? Is there any justification in the popular vision of industrial development as being characterized by 'jobless growth'?

Our empirical framework also allows us to investigate firm-level productivity dynamics. Previous theoretical contributions have suggested that there may be 'dynamic increasing returns' (à la Kaldor-Verdoorn) according to which firm growth would be positively associated with productivity growth. On the other hand, Penrose (1959) suggested that firm growth is associated with decreases in productive efficiency, because planning for growth takes managerial focus away from keeping production costs down. The association between firm growth and productivity has not been resolved in theoretical discussions, and we therefore consider it to be an empirical question.

Structure of the paper 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. The robustness of these results is explored in Section 5. In Section 6 we discuss these results, and conclude in Section 7.

2 Database and summary statistics

This research draws upon the EAE databank collected by SESSI and provided by the French Statistical Office (INSEE).[1,2] This database contains longitudinal data on a virtually exhaustive panel of French firms with 20 employees or more over the period 1989-2004. We restrict our analysis to the manufacturing sectors.[3] For statistical consistency, we only utilize the period 1996-2004 and we consider only continuing firms over this period. Firms that entered midway through 1996 or exited midway through 2004 have been removed. Since we want to focus on internal, 'organic' growth rates, we exclude firms that have undergone any kind of modification of structure, such as merger or acquisition. In contrast to some previous studies (e.g. Bottazzi et al. (2001)), we do not attempt to construct 'super-firms' by treating firms that merge at some stage during the period under study as if they had been merged from the start of the study, because of limited information on restructuring activities. To start with we had observations for around 22 000 firms per year for each year of the period,[4] but at this stage we have a balanced panel of 8503 firms for each year.

In order to avoid misleading values and the generation of NANs[5] whilst taking logarithms and ratios, we now retain only those firms with strictly positive values for Gross Operating Surplus (GOS),[6] Value Added (VA), and employees in each year. This creates some missing values, especially for our growth of gross operating surplus variable (see Table 2). By restricting ourselves to strictly positive values for the gross operating surplus, we lose 13-14% of the observations in 1997 and 2000 whereas we lose about 26% of the observations in 2004.

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 pro-

[1]The EAE databank has been made available to the author under the mandatory condition of censorship of any individual information.

[2]This database has already featured in several other studies into firm growth – see Bottazzi et al. (2005), Coad (2005), and Coad (2006).

[3]More specifically, we examine firms in the two-digit NAF sectors 17-36, where firms are classified according to their sector of principal activity (the French NAF classification matches with the international NACE and ISIC classifications). We do not include NAF sector 37, which corresponds to recycling industries.

[4]22 319, 22 231, 22 305, 22 085, 21 966, 22 053, 21 855, 21 347 and 20 723 firms respectively.

[5]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.

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

Table 1: Summary statistics after cleaning the data

	Mean	Std. Dev.	10%	25%	Median	75%	90%	obs.
1996								
Sales	99328	340574	11733	17531	30693	68306	179629	8503
Empl	101.01	235.79	25	32	45	86	190	8503
2000								
Sales	125609	447165	13670	21199	38342	84011	227723	8503
Empl	106.16	234.71	27	34	47	93	200	8503
2004								
Sales	135671	527168	13237	21128	40046	88751	239982	8503
Empl	104.35	238-96	25	33	47	92	200	8503

Table 2: Summary statistics for the growth rate series

	Mean	Std Dev	10%	25%	50%	75%	90%	obs
1997								
Empl. growth	0.0000	0.1352	-0.1049	-0.0437	-0.0096	0.0417	0.1156	8489
Sales growth	0.0000	0.2314	-0.1759	-0.0740	-0.0038	0.0785	0.1803	8503
GOS growth	0.0000	0.8068	-0.7630	-0.3152	0.0043	0.3191	0.7675	7383
Prod. growth	0.0000	0.2173	-0.1956	-0.0910	-0.0019	0.0861	0.1987	8468
2000								
Empl. growth	0.0000	0.1333	-0.1168	-0.0526	-0.0117	0.0466	0.1317	8503
Sales growth	0.0000	0.2084	-0.1708	-0.0800	-0.0077	0.0752	0.1845	8503
GOS growth	0.0000	0.7988	-0.7688	-0.2995	-0.0029	0.3232	0.7550	7323
Prod. growth	0.0000	0.2181	-0.2025	-0.0936	-0.0007	0.0905	0.2068	8488
2004								
Empl. growth	0.0000	0.1295	-0.1157	-0.0373	0.0164	0.0475	0.1050	8502
Sales growth	0.0000	0.2191	-0.1763	-0.0729	-0.0002	0.0810	0.1779	8503
GOS growth	0.0000	0.8603	-0.8465	-0.3151	0.0176	0.3257	0.8312	6276
Prod. growth	0.0000	0.2580	-0.2138	-0.0904	0.0001	0.0931	0.2150	8462

ductivity[7] for firm i at time t.

In keeping with previous work (e.g. Bottazzi et al. (2005)) the growth rate distributions have been normalized around zero in each year which effectively removes any common trends such as inflation.[8]

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 stats of the growth rate distributions.

Figure 1 shows the unconditional growth rates distributions for our four variables of interest. These growth rates distributions are visibly heavy-tailed.[9] This gives an early hint that standard regression estimators

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

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

[9]Bottazzi et al. (2005) present a parametric investigation of the distribution of sales growth rates of French

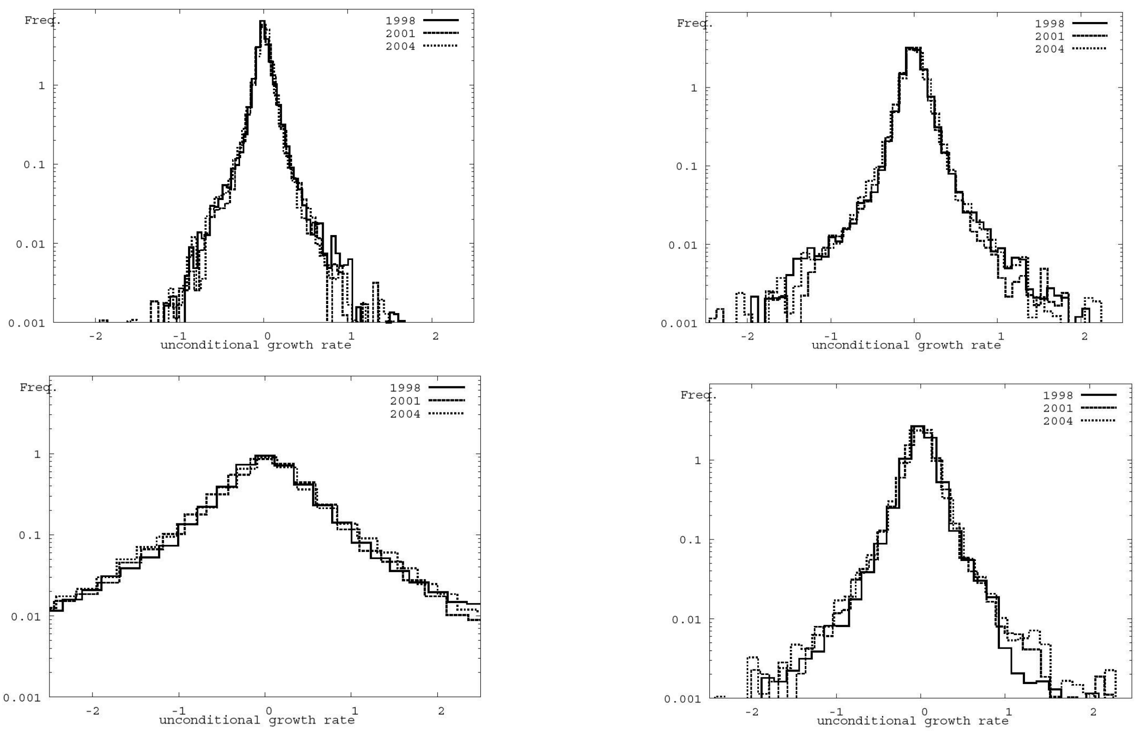

Figure 1: Distribution of the unconditional growth rates of our sample of French manufacturing firms. Top left: employment growth. Top right: sales growth. Bottom left: growth of gross operating surplus. Bottom right: growth of labour productivity. Note the log scale on the y axis.

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 and Figure 2 show 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 elsewhere (Delmar et al. (2003)). The largest correlation (0.5959) is between growth of gross operating surplus and that of labour productivity. Indeed, the positive correlation between profits and productivity has also been observed in work on Italian data – see Bottazzi et al. (2006). We also observe relatively large positive correlations between these two variables and the growth of sales (0.3922 and 0.4452 respectively). Although there is a large 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.

---

manufacturing firms. In particular, they estimate the functional form of the growth rates density in terms of the Subbotin family of distributions (of which the Gaussian (normal) and the Laplace (symmetric exponential) distributions are special cases). They observe that, in the case of French manufacturing firms, the growth rates density is even fatter tailed than the Laplace.

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.	67978			
(Sp. Rank)	1.0000			
(p-value)	0.0000			
Sales growth	0.3710	1.0000		
p-value	0.0000	0.0000		
obs.	67978	68024		
(Sp. Rank)	0.3294	1.0000		
(p-value)	0.0000	0.0000		
GOS growth	0.0754	0.3922	1.0000	
p-value	0.0000	0.0000	0.0000	
obs.	56554	56594	56594	
(Sp. Rank)	0.0750	0.4738	1.0000	
(p-value)	0.0000	0.0000	0.0000	
Prod. growth	-0.2073	0.4452	0.5959	1.0000
p-value	0.0000	0.0000	0.0000	0.0000
obs.	67796	67796	56545	67796
(Sp. Rank)	-0.2458	0.4560	0.7199	1.0000
(p-value)	0.0000	0.0000	0.0000	0.0000

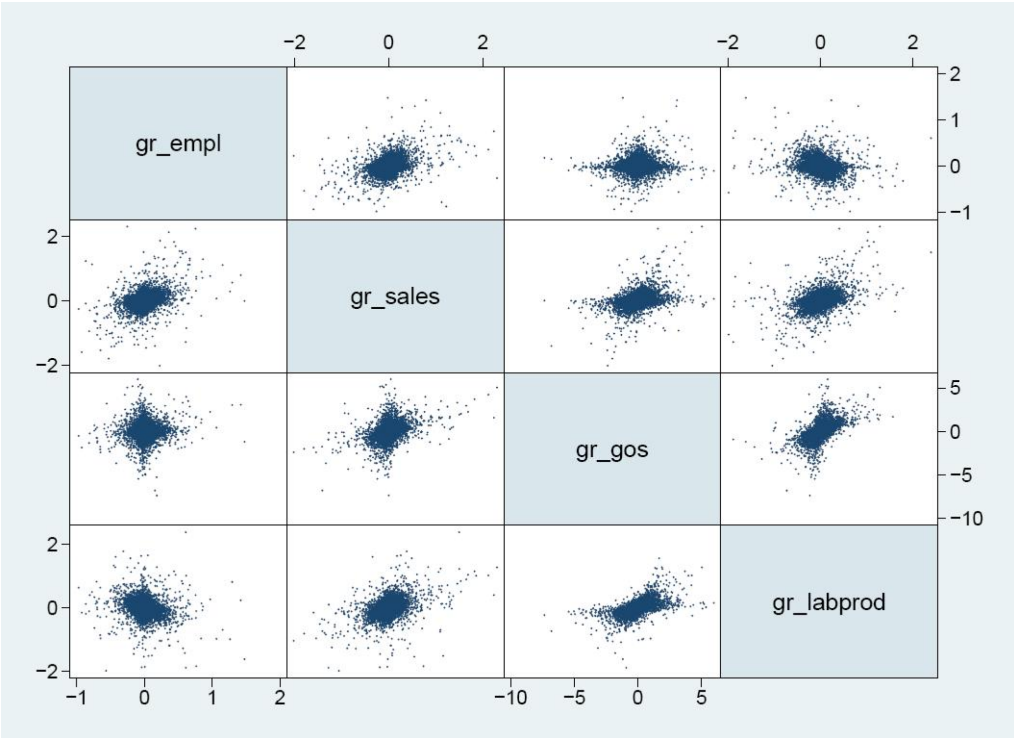

Figure 2: Scatterplot matrix of contemporaneous values of employment growth, sales growth, growth of GOS and growth of productivity in a typical year (2000).

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.

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 this dataset has not observed any dependence of sales growth on size (Bottazzi et al. (2005)), we do not attempt clean the series of size dependence before applying the VAR. However, we explore how our results change across firm size groups in detail in Section 5

We estimate equation (2) via 'reduced-form' VARs, which do not impose any *a priori* causal structure on the relationships between the variables, and are therefore suitable for the preliminary nature of our analysis. 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 may provide unreliable results, and as argued in Bottazzi et al. (2005) we would prefer Least Absolute Deviation (LAD) estimation.

Allowing for firm-specific fixed effects A further reason why OLS (and also LAD) estimation of equation (2) is likely to perform poorly is if there is unobserved heterogeneity between firms in the form of time-invariant firm-specific effects. If these 'fixed effects' are correlated with the explanatory variables, then OLS (and LAD) estimates will be biased. One way of doing accounting for these fixed effects would be to introduce a dummy variable for each firm and to include this in the regression equation to obtain a standard 'fixed-effects' panel data model. The drawback with this, however, is that the inclusion of lagged dependent variables can be a source of bias for fixed-effect estimation of dynamic panel-data models. The intuition is that the fixed effect would be in some sense 'double-counted' if the dependent variable is included in the regression equation at time t and also at at previous times due to the lag structure (this problem is known as 'Nickell-bias' after Nickell (1981)). Nickell-bias is often observed to be rather small, however, and so its importance is a matter of debate.

This 'Nickell-bias' problem 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 confidence intervals surrounding the resulting estimates will be large. 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 (2005)). IV estimation of a panel VAR with weak instruments thus leads to imprecise estimates.

Binder et al. (2005) present a panel VAR model which can include firm-specific fixed effects but that does not require the use of instrumental variables. The model is estimated using Quasi-maximum-likelihood optimization techniques. They propose the following model:

$$w_{it} = (I_m - \Phi)\mu_i + \Phi w_{i,t-1} + \epsilon \tag{3}$$

where μ corresponds to the firm-specific fixed effects and Φ is the $m \times m$ coefficient matrix to be estimated. ϵ is the usual vector of disturbance terms. BHP (2005) present evidence from Monte Carlo simulations that demonstrates that their estimator is more efficient (i.e. the estimates have lower standard errors) than IV GMM. The drawback with the BHP estimator for this particular application, however, is that it assumes normally distributed errors (whereas the distributions of firm growth rates are approximately Laplace-distributed).

In this paper our estimator of choice is therefore the LAD estimator, which is best suited to the case of Laplacian error terms.

Causality or association? Our intentions in this paper are to summarize the comovements of the growth series. We remind the reader of the important distinction between correlation and causality. We have no strong *a priori* theoretical positions, and we make no attempt at any serious identification of the underlying causality at this early stage, instead preferring to describe the associations. Indeed, much can be learned simply by considering the associations between the variables without mentioning issues of causality (see Moneta (2005) for a discussion).

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 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 was observed by Bottazzi et al. (2005) and is explored in Coad (2006). 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 (see Coad (2006)). 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 of a similar order 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 GOS growth even at the second lag.

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 0.15 percentage points in the following year. Similarly, a 1 percentage point increase in sales growth can be expected to be followed by a 0.04 percentage point increase in employment growth. 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.) However, we warn against putting too much faith in specific point estimates at this early stage.

We also observe that growth in labour productivity seems to be preceded by growth of employment and of sales, although the (positive) coefficient is rather small.

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.

Table 4: OLS estimation of equation (2).

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	**-0.1422**	**0.0403**	-0.0002	0.0202					0.0224	50269
t-stat	-9.2	4.79	-0.16	1.75						
Sales growth	**0.1217**	**-0.2502**	**0.0061**	0.0056					0.0468	50271
t-stat	6.15	-16.24	2.89	0.36						
GOS growth	**0.1354**	**0.1062**	**-0.3820**	**0.2266**					0.1109	46818
t-stat	2.49	2.83	-30.16	4.27						
Prod. growth	0.0151	-0.0066	**0.0070**	**-0.2776**					0.0545	50249
t-stat	0.79	-0.52	3.46	-15.26						
Empl. growth	**-0.1412**	**0.0559**	0.0009	0.0206	-0.0050	0.0091	0.0002	**0.0325**	0.0242	40917
t-stat	-7.97	5.72	0.59	1.51	-0.44	1.16	0.11	3.47		
Sales growth	**0.1771**	**-0.2821**	**0.0091**	0.0080	**0.1199**	**-0.1590**	**0.0068**	0.0161	0.0573	40918
t-stat	8.11	-15.98	3.59	0.45	6.69	-10.49	3.05	1.04		
GOS growth	**0.2863**	**0.1509**	**-0.4958**	**0.3845**	0.0482	0.0296	**-0.2128**	**0.1034**	0.1444	38077
t-stat	4.85	3.52	-34.99	6.61	0.95	0.79	-18.09	2.04		
Prod growth	0.0080	-0.0013	**0.0088**	**-0.3308**	-0.0038	-0.0022	**0.0058**	**-0.1669**	0.0723	40901
t-stat	0.36	-0.09	3.31	-15.07	-0.22	-0.17	2.5	-9.73		

Table 5: Fixed-effect estimation of equation (2).

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	**-0.2983**	**0.0383**	0.0016	-0.0062					0.0195	50269
t-stat	-17.21	4.53	1.30	-0.56						
Sales growth	0.0301	**-0.3195**	**0.0071**	-0.0129					0.0439	50271
t-stat	1.38	-19.12	3.19	-0.77						
GOS growth	0.0214	0.0703	**-0.4229**	**0.1678**					0.1102	46818
t-stat	0.35	1.70	-30.34	2.91						
Prod. growth	0.0048	-0.0049	**0.0071**	**-0.3412**					0.0544	50249
t-stat	0.23	-0.35	3.28	-17.81						
Empl. growth	**-0.3710**	**0.0440**	0.0026	-0.0007	**-0.2170**	0.0101	**0.0039**	-0.0011	0.0138	40917
t-stat	-16.40	4.30	1.52	-0.05	-12.57	1.15	2.35	-0.10		
Sales growth	**0.0900**	**-0.4416**	**0.0089**	-0.0021	0.0283	**-0.2813**	**0.0110**	-0.0070	0.0490	40918
t-stat	3.83	-23.54	3.38	-0.12	1.42	-17.08	4.52	-0.42		
GOS growth	**0.2077**	0.0540	**-0.6114**	**0.3891**	-0.0421	-0.0329	**-0.2970**	0.0835	0.1418	38077
t-stat	3.09	1.16	-38.40	6.10	-0.69	-0.79	-21.15	1.40		
Prod. growth	0.0034	-0.0118	**0.0083**	**-0.4595**	-0.0117	-0.0095	**0.0100**	**-0.2770**	0.0716	40901
t-stat	0.14	-0.77	3.06	-21.22	-0.55	-0.67	3.94	-14.57		

Table 6: LAD estimation of equation (2).

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	0.0039	**0.0372**	**-0.0019**	**0.0340**					0.0069	50269
t-stat	0.85	12.02	-2.76	8.58						
Sales growth	**0.1457**	**-0.0935**	**-0.0021**	**0.0374**					0.0058	50271
t-stat	24.54	-23.26	-2.30	7.27						
GOS growth	**0.1715**	**0.1178**	**-0.3190**	**0.2323**					0.0348	46818
t-stat	6.24	6.31	-72.83	9.71						
Prod. growth	**0.0330**	**0.0097**	-0.0015	**-0.2035**					0.0210	50249
t-stat	4.58	1.99	-1.40	-32.54						
Empl. growth	-0.0015	**0.0440**	-0.0009	**0.0293**	**0.0240**	**0.0164**	-0.0015	**0.0236**	0.0094	40917
t-stat	-0.32	13.86	-1.15	7.29	5.30	5.21	-1.93	5.83		
Sales growth	**0.1595**	**-0.0987**	-0.0002	**0.0296**	**0.0668**	**-0.0381**	-0.0003	0.0059	0.0068	40918
t-stat	20.75	-18.39	-0.15	4.34	8.73	-7.15	-0.26	0.86		
GOS growth	**0.2701**	**0.1789**	**-0.4231**	**0.3753**	-0.0074	**0.0883**	**-0.1567**	0.0452	0.0488	38077
t-stat	9.24	8.73	-82.60	14.41	-0.25	4.34	-30.96	1.74		
Prod. growth	**0.0276**	**0.0189**	-0.0019	**-0.2402**	-0.0013	0.0076	0.0012	**-0.1214**	0.0270	40901
t-stat	2.98	2.93	-1.25	-29.26	-0.14	1.18	0.77	-14.70		

We also observe that the R^2 statistics are rather low, always lower than 5% in our preferred LAD specification (Table 6).

5 Robustness 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 profits growth and labour productivity growth. This high degree of multicollinearity may lead to excessively sensitive coefficient estimates. To explore this sensitivity, we repeat the analysis excluding either the productivity growth or the GOS growth variables, and we hope to obtain similar coefficient estimates to those obtained earlier.

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 feed-back effect on subsequent employment growth, of a similar magnitude to that found in Table 6. However, in this simplified specification we no longer observe the direct influence of employment growth on subsequent profits growth (or on productivity growth). Another difference concerns the relationship between growth of GOS and subsequent growth of employment or sales.

The results obtained from the different specifications are admittedly different in a few respects, and so we should be especially cautious in drawing conclusions from this rather preliminary analysis.

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 (2006) shows how the time scale of growth processes varies between small and large firms. For example, 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 1996, 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 10, therefore, we use an alternative methodology for sorting the firms into size groups (i.e. according to mean number of employees 1996-2004).

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))'.

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	**-0.0205**	**0.0529**	**0.0013**				0.0060	50277
t-stat	-5.64	20.86	2.32					
Sales growth	**0.1194**	**-0.0767**	0.0014				0.0054	50279
t-stat	23.06	-21.25	1.77					
GOS growth	-0.0073	**0.2144**	**-0.2845**				0.0341	46826
t-stat	-0.31	13.10	-73.61					
Empl. growth	**-0.0216**	**0.0581**	**0.0021**	**0.0119**	**0.0260**	**0.0013**	0.0087	40924
t-stat	-6.03	22.11	3.35	3.32	10.00	2.09		
Sales growth	**0.1381**	**-0.0850**	**0.0024**	**0.0655**	**-0.0358**	0.0004	0.0066	40925
t-stat	24.62	-20.72	2.50	11.72	-8.83	0.36		
GOS growth	-0.0004	**0.3269**	**-0.3633**	-0.0276	**0.1059**	**-0.1475**	0.0472	38084
t-stat	-0.02	19.82	-89.52	-1.25	6.54	-36.76		

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))'.

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	-0.0034	**0.0428**	**0.0186**				0.0075	59332
t-stat	-0.97	17.84	8.98					
Sales growth	**0.1286**	**-0.0888**	**0.0230**				0.0053	59334
t-stat	24.93	-25.02	7.50					
Prod. growth	-0.0030	**0.0111**	**-0.2287**				0.0258	59266
t-stat	-0.52	2.80	-65.88					
Empl. growth	-0.0068	**0.0473**	**0.0217**	**0.0221**	**0.0178**	**0.0172**	0.0109	50809
t-stat	-1.81	17.59	9.44	5.83	6.61	7.21		
Sales growth	**0.1496**	**-0.0982**	**0.0221**	**0.0620**	**-0.0391**	0.0025	0.0066	50810
t-stat	26.46	-24.43	6.43	10.90	-9.69	0.69		
Prod. growth	-0.0085	**0.0298**	**-0.2837**	**-0.0313**	**0.0145**	**-0.1486**	0.0354	50751
t-stat	-1.25	6.15	-68.03	-4.59	3.00	-34.52		

Table 9: LAD estimation of equation (2) across different size groups. Firms sorted into size groups according to their initial size (sales in 1996). 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	**-0.0697**	**0.0306**	0.0001	**0.0308**	0.0079	9762
t-stat	-3.81	2.42	0.06	2.01		
Sales growth	**0.1547**	**-0.1489**	-0.0012	0.0405	0.0106	9762
t-stat	5.44	-5.95	-0.49	1.54		
GOS growth	0.2102	0.0945	**-0.3039**	0.0564	0.0412	8931
t-stat	1.87	1.19	-12.87	0.49		
Prod. growth	**0.0990**	-0.0030	0.0003	**-0.2480**	0.0388	9762
t-stat	3.39	-0.15	0.10	-10.85		
Size group 2						
Empl. growth	-0.0116	**0.0348**	**-0.0037**	**0.0490**	0.0069	10292
t-stat	-0.71	3.79	-2.35	4.18		
Sales growth	**0.1800**	**-0.1452**	0.0005	0.0339	0.0106	10292
t-stat	7.28	-8.68	0.19	1.75		
GOS growth	-0.0223	**0.1304**	**-0.2861**	0.0880	0.0348	9633
t-stat	-0.27	2.56	-12.04	1.06		
Prod. growth	0.0203	0.0048	0.0008	**-0.2284**	0.0260	10288
t-stat	0.79	0.27	0.35	-11.48		
Size group 3						
Empl. growth	0.0004	**0.0230**	-0.0015	**0.0503**	0.0076	10166
t-stat	0.03	3.03	-1.18	5.25		
Sales growth	**0.1623**	**-0.1155**	-0.0040	**0.0753**	0.0065	10166
t-stat	8.75	-7.68	-1.45	3.91		
GOS growth	**0.2829**	0.0045	**-0.3263**	**0.3062**	0.0357	9501
t-stat	3.17	0.06	-11.47	2.73		
Prod. growth	0.0400	-0.0035	-0.0025	**-0.2028**	0.0239	10166
t-stat	1.49	-0.20	-0.71	-8.10		
Size group 4						
Empl. growth	0.0053	**0.0491**	-0.0015	0.0158	0.0071	9957
t-stat	0.40	5.67	-1.02	1.46		
Sales growth	**0.1147**	**-0.0641**	-0.0027	**0.0323**	0.0030	9958
t-stat	5.63	-4.08	-1.02	2.26		
GOS growth	0.0652	**0.2084**	**-0.3691**	**0.2732**	0.0422	9244
t-stat	0.66	3.20	-11.34	2.66		
Prod. growth	-0.0296	**0.0462**	-0.0048	**-0.1850**	0.0157	9953
t-stat	-1.09	2.85	-1.42	-7.04		
Size group 5						
Empl. growth	**0.1309**	**0.0486**	-0.0016	**0.0253**	0.0237	10092
t-stat	8.67	7.66	-1.01	3.65		
Sales growth	**0.1587**	-0.0040	-0.0014	0.0266	0.0061	10093
t-stat	5.60	-0.26	-0.55	1.79		
GOS growth	**0.1851**	**0.2978**	**-0.2939**	**0.2161**	0.0233	9509
t-stat	2.05	4.57	-8.91	2.46		
Prod. growth	-0.0406	0.0254	-0.0005	**-0.1566**	0.0102	10080
t-stat	-1.38	1.06	-0.10	-5.52		

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 (more on this in Coad (2006)).

We also observe that, as we move towards larger firms, the contribution of sales growth to both employment growth and growth of profits seems to increase in magnitude. It is also interesting to 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.

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.[10]

The regression results are presented in Table 11. Our results emphasize a certain degree of heterogeneity between diverse sectors.

For example, in the Pharmaceuticals 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 growth of profits, in the Machinery/Equipment and Textiles sectors. We also observe that productivity growth is relatively strongly associated with growth of profits in the Textiles sector.

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 1998, 2000. 2002 and 2004). The results are presented in Table 12.

We do indeed observe that the regression results vary over time. In particular, the contribution of sales growth and employment growth to the growth of profits seems to vary considerably. Employment growth seems to have a relatively consistent effect on the growth of sales, however.

5.5 Asymmetric effects for growing or shrinking firms

One potential caveat of the preceding analysis is that there may be asymmetric effects for firms that increase employment and for firms that decrease employment. It may be relatively easy for firms to hire new employees while firing costs may limit their ability to lay workers off. In this section we therefore explore differential

[10]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 for our empirical model.

Table 10: LAD estimation of equation (2) across different size groups. Firms sorted into size groups according to their mean size (average number of employees 1996-2004). 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	**-0.0826**	**0.0319**	0.0003	**0.0309**	0.0129	10029
t-stat	-5.36	3.56	0.18	3.08		
Sales growth	**0.1127**	**-0.1397**	0.0019	0.0248	0.0089	10029
t-stat	5.46	-7.66	0.78	1.45		
GOS growth	0.1853	0.0108	**-0.2909**	**0.1741**	0.0370	9294
t-stat	1.94	0.15	-11.07	2.25		
Prod. growth	**0.0828**	0.0020	-0.0005	**-0.2310**	0.0309	10020
t-stat	2.69	0.12	-0.20	-9.73		
Size group 2						
Empl. growth	**-0.0612**	**0.0273**	-0.0005	0.0174	0.0051	10172
t-stat	-3.90	3.14	-0.28	1.53		
Sales growth	**0.1282**	**-0.1417**	-0.0022	0.0221	0.0107	10172
t-stat	5.71	-7.78	-0.94	1.20		
GOS growth	0.1707	0.0909	**-0.3208**	0.1344	0.0386	9454
t-stat	1.91	1.82	-11.90	1.42		
Prod. growth	**0.0789**	-0.0019	0.0002	**-0.2298**	0.0279	10171
t-stat	3.03	-0.12	0.06	-10.19		
Size group 3						
Empl. growth	-0.0006	**0.0308**	**-0.0043**	**0.0443**	0.0072	10156
t-stat	-0.05	4.67	-3.07	5.13		
Sales growth	**0.1226**	**-0.0929**	-0.0047	**0.0426**	0.0049	10158
t-stat	6.76	-5.90	-1.72	2.64		
GOS growth	0.0554	**0.1877**	**-0.3332**	**0.2393**	0.0386	9512
t-stat	0.58	3.11	-14.53	2.73		
Prod. growth	0.0310	0.0097	-0.0006	**-0.2156**	0.0228	10155
t-stat	1.23	0.55	-0.17	-9.28		
Size group 4						
Empl. growth	**0.0670**	**0.0531**	-0.0012	**0.0309**	0.0121	9903
t-stat	4.80	5.52	-1.17	3.09		
Sales growth	**0.1927**	**-0.0696**	-0.0033	**0.0642**	0.0076	9903
t-stat	8.99	-4.41	-1.20	3.37		
GOS growth	**0.2840**	0.0991	**-0.3577**	**0.3899**	0.0379	9166
t-stat	2.89	1.76	-9.80	3.35		
Prod. growth	-0.0009	0.0194	**-0.0073**	**-0.1558**	0.0163	9900
t-stat	-0.05	1.18	-2.87	-7.71		
Size group 5						
Empl. growth	**0.1335**	**0.0606**	-0.0035	**0.0402**	0.0263	10009
t-stat	7.26	6.82	-1.96	3.99		
Sales growth	**0.1832**	-0.0035	-0.0022	**0.0408**	0.0086	10009
t-stat	7.74	-0.22	-0.81	2.93		
GOS growth	0.1909	**0.2519**	**-0.2857**	0.2412	0.0235	9392
t-stat	1.66	2.93	-9.08	2.12		
Prod. growth	-0.0421	0.0289	0.0003	**-0.1595**	0.0105	10003
t-stat	-1.44	1.39	0.07	-5.96		

Table 11: LAD estimation of equation (2) across different industries. Standard errors (and hence t-statistics) obtained from using 1000 bootstrap replications.

w_t	β_{t-1}					
	Empl. gr.	Sales gr.	GOS gr.	Prod. growth	R^2	obs
NAF 33: Precision instruments						
Empl. growth	**0.0939**	**0.0721**	0.0008	0.0149	0.0195	1561
t-stat	2.53	2.95	0.26	0.55		
Sales growth	**0.2458**	-0.0766	-0.0046	0.0739	0.0120	1561
t-stat	3.63	-1.41	-0.95	1.26		
GOS growth	-0.0172	0.2630	**-0.2924**	0.0852	0.0406	1445
t-stat	-0.07	1.34	-4.23	0.36		
Prod. growth	-0.0583	0.0741	-0.0025	**-0.3129**	0.0322	1561
t-stat	-0.99	1.52	-0.45	-5.95		
NAF 27: Basic metals						
Empl. growth	0.0120	**0.0553**	-0.0023	0.0024	0.0074	1236
t-stat	0.33	2.50	-0.50	0.10		
Sales growth	0.1060	-0.0875	-0.0111	0.0717	0.0069	1236
t-stat	1.67	-1.77	-1.71	1.42		
GOS growth	0.3084	-0.0253	**-0.3701**	0.2307	0.0552	1152
t-stat	1.36	-0.24	-4.94	1.00		
Prod. growth	-0.1107	-0.0387	-0.0108	**-0.1921**	0.0342	1235
t-stat	-1.66	-0.83	-1.27	-3.27		
NAF 29: Machinery and equipment						
Empl. growth	-0.0016	**0.0307**	0.0002	0.0140	0.0038	5097
t-stat	-0.08	3.00	0.12	1.10		
Sales growth	**0.2059**	**-0.1896**	0.0010	0.0431	0.0151	5097
t-stat	5.30	-7.29	0.22	1.36		
GOS growth	0.1371	**0.2054**	**-0.3506**	0.0937	0.0493	4698
t-stat	0.96	2.05	-8.28	0.65		
Prod. growth	0.0072	-0.0136	0.0005	**-0.2332**	0.0278	5097
t-stat	0.17	-0.54	0.13	-6.08		
NAF 17: Textiles						
Empl. growth	0.0133	**0.0512**	0.0000	0.0103	0.0061	3205
t-stat	0.72	2.70	-0.01	0.78		
Sales growth	0.0660	0.0429	0.0030	-0.0491	0.0051	3205
t-stat	1.78	1.54	0.55	-1.76		
GOS growth	0.2778	**0.3242**	**-0.3617**	**0.2510**	0.0383	2925
t-stat	1.89	3.25	-7.27	2.36		
Prod. growth	0.0521	0.0411	-0.0064	**-0.1773**	0.0178	3201
t-stat	0.84	0.99	-0.80	-3.43		

Table 12: LAD estimation of equation (2) for four different years: 1998, 2000, 2002 and 2004. Standard errors (and hence t-statistics) obtained from using 1000 bootstrap replications.

w_t	β_{t-1}					
	Empl. gr.	Sales gr.	GOS gr.	Prod. growth	R^2	obs
1998						
Empl. growth	0.0043	0.0194	-0.0018	**0.0393**	0.0037	7366
t-stat	0.29	1.84	-1.00	3.11		
Sales growth	**0.1419**	**-0.1226**	**-0.0072**	**0.0641**	0.0086	7367
t-stat	6.15	-6.62	-2.48	3.08		
GOS growth	0.0979	0.0952	**-0.2864**	0.1701	0.0341	7075
t-stat	0.98	1.39	-10.41	1.65		
Prod. growth	0.0475	-0.0145	-0.0015	**-0.2052**	0.0276	7365
t-stat	1.94	-0.87	-0.52	-8.86		
2000						
Empl. growth	-0.0048	**0.0689**	-0.0006	0.0146	0.0105	7384
t-stat	-0.30	7.28	-0.35	1.35		
Sales growth	**0.1690**	**-0.1259**	-0.0041	0.0404	0.0078	7384
t-stat	5.61	-5.95	0.66	1.83		
GOS growth	0.2114	0.0861	**-0.3310**	**0.2564**	0.0400	7019
t-stat	2.40	1.34	-9.29	2.72		
Prod. growth	0.0273	-0.0038	0.0031	**-0.2178**	0.0252	7380
t-stat	0.73	-0.17	0.75	-6.39		
2002						
Empl. growth	0.0000	0.0000	0.0000	0.0000	0.0000	7279
t-stat	0.00	0.00	0.00	0.00		
Sales growth	**0.0911**	**-0.0664**	-0.0023	0.0124	0.0040	7279
t-stat	3.98	-3.18	-0.67	0.67		
GOS growth	-0.0200	**0.2225**	**-0.3175**	**0.1443**	0.0344	6679
t-stat	-0.15	2.32	-9.73	1.18		
Prod. growth	-0.0095	.0123	-0.0041	**-0.2105**	0.0195	7274
t-stat	-0.29	0.52	-1.15	-9.07		
2004						
Empl. growth	-0.0015	0.0178	0.0002	0.0077	0.0004	6497
t-stat	-0.17	1.51	0.25	0.86		
Sales growth	**0.1706**	**-0.0642**	-0.0041	0.0296	0.0063	6497
t-stat	5.14	-2.68	-1.36	1.38		
GOS growth	**0.2746**	**0.2910**	**-0.3978**	**0.4280**	0.0453	5898
t-stat	2.42	3.27	-11.63	3.41		
Prod. growth	**0.0748**	0.0296	**-0.0088**	**-0.1311**	0.0155	6494
t-stat	2.19	1.59	-2.27	-4.16		

Table 13: Quantile regression estimation of equation (2), focusing on the relationship between profits growth (t-1) and employment growth (t). 50269 observations. Standard errors (and hence t-statistics) obtained from using 100 bootstrap replications.

	10%	25%	50%	75%	90%
Coeff.	0.0007	-0.0003	**-0.0019**	**-0.0030**	-0.0033
t-stat	0.40	-0.34	-2.94	-2.61	-1.37
R^2	0.0098	0.0067	0.0069	0.0074	0.0084

effects of the explanatory variables over the employment growth 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).)

Figure 3 and Table 13 present the quantile regression coefficient estimates. Roughly speaking, the lower quantiles (closer to 0) represent firms with net employment losses whilst the upper quantiles (closer to 1) represent firms with net employment gains. We observe that the coefficient on lagged growth of profits is slightly higher at the lower quantiles. This suggests that, for those firms that are shedding employees, growth of profits seems to attenuate the firing of employees. Put differently, if a firm is firing employees, it can be expected to fire even more workers if it is experiencing poor financial performance. The magnitude of this effect is not very large, however.

We also check for analogous effects in the relationships between other pairs of variables by looking at the quantile regression plots. Concerning the autocorrelation coefficients, we find results similar to those reported in Coad (2006). For the other relationships, we sometimes obtain interesting results.[11] We therefore conclude this section by acknowledging that although there may be asymmetric effects for growing and shrinking firms, these asymmetries do not appear to be so large as to make our previous estimates unhelpful.

6 Discussion

The coefficient estimates from the preceding section have allowed us to observe the comovements of the four series – employment growth, sales growth, growth of the gross operating surplus, and growth of labour productivity.

Figure 4 provides a simple summary representation of our results, which is based on an (admittedly subjective) synthesis of the LAD estimates reported in Tables 6, 7, and 8. It should certainly be remembered, however, that we cannot rely too heavily on our regression estimates because our results do appear to be sensitive to regression specification, firm size, sector of activity, and year.

Figure 4 illustrates that employment growth appears to contribute positively to sales growth, which in turn is associated with subsequent profits growth. These early results provide (limited) support to the idea that employment growth may perhaps be seen as the 'stimulus' which drives growth in other domains of the firm. Indeed, among the series that we consider here, employment growth is the firm's main decision variable.

Our results allow us to comment on two theories of firm growth. First, the replicator dynamics model, frequently found in neo-Schumpeterian simulation 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

[11]For example, there is considerable variation in the coefficient on lagged employment growth on growth of profits. At the lower quantiles of profits growth, lagged employment growth has a positive effect whilst having a negative effect at the upper quantiles.

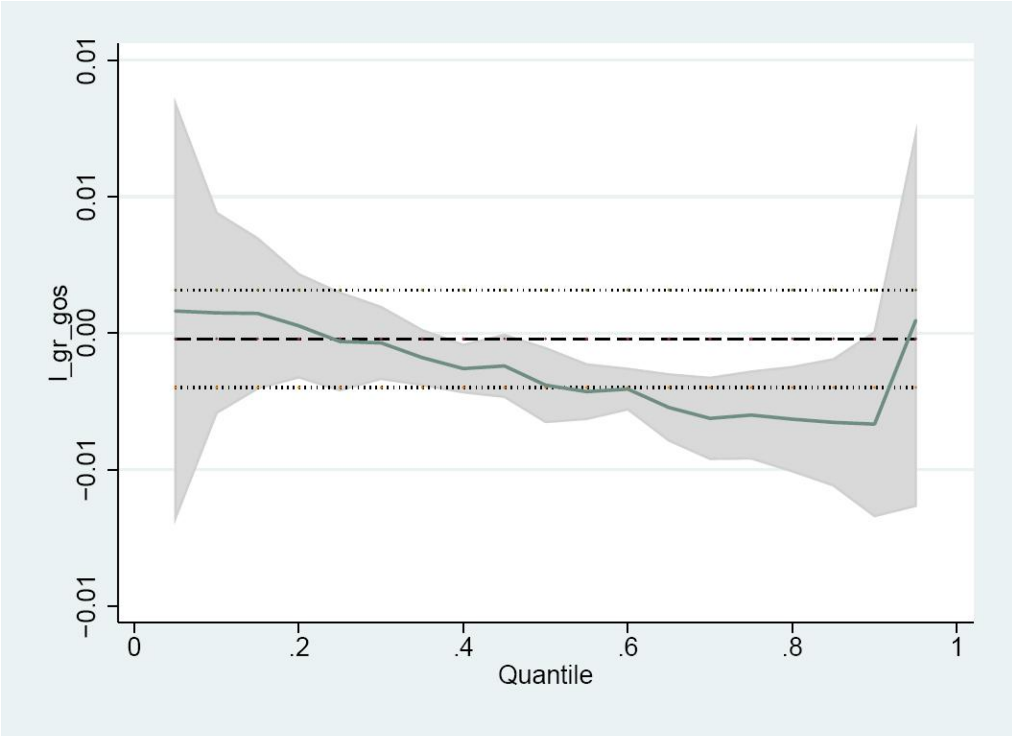

Figure 3: Quantile regression analysis of the relationship between growth of profits $(t-1)$ and employment growth (t). Variation in the coefficient on lagged growth of profits over the conditional quantiles of the employment growth rate distribution. Conditional quantiles (on the x-axis) range from 0 (for the extreme negative-growth firms) to 1 (for the fastest-growing firms). Confidence intervals (non-bootstrapped) extend to 95% confidence intervals in either direction. Horizontal lines represent OLS estimates with 95% confidence intervals. Graphs made using the 'grqreg' Stata module (Azevedo (2004)).

share (see Coad (2005) for a discussion). 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. The results presented here do not offer much support to these two theories of firm growth. Instead, it seems that firm growth is very much a discretionary phenomenon. The decision to take on new employees seems to be largely exogenous, and the mere generation of profits certainly does not automatically imply that these profits will be reinvested in the firm.

Two stories of firm growth Our results are consistent with (at least) two possible stories of firm growth.

First, one may believe that firms are incapable of accurately seeing into the future. At any time some firms may take a risk and decide to grow, and this increase in resources eventually results in an increase in sales and also an increase in profits. Other firms may be hesitant about hiring new employees, and thus they may miss out on growth opportunities.[12]

[12] Remember however that we have excluded those unfortunate firms that obtained negative profits – which is a source of sample selection bias. We should thus be extremely wary of saying that employment growth always leads to sales or profits growth, because it may be that in some cases employment growth leads to failure.

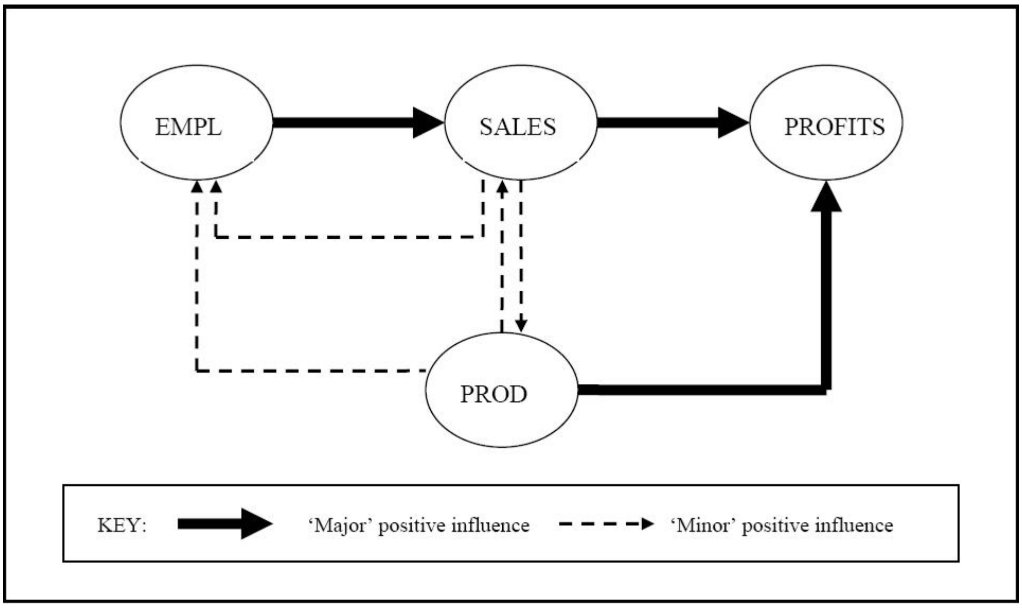

Figure 4: A stylized depiction of the process of firm growth, based on the PVAR(1) specification in Table 6

Second, an alternative view is that firms can accurately anticipate the evolution of the market (demand shocks or technology shocks, for example). These rational firms take on new employees with the aim of exploiting these anticipated opportunities. In this case, employment growth is merely a response to new information about market conditions. In this case it would be quite incorrect to say that employment growth causes sales growth, because it is the successful anticipation of sales growth opportunities that leads to employment growth.

We note however that many intermediate cases are also possible, whereby managers do not know for sure how the business climate will evolve but they are willing to take a bet on a 'hunch' they might have. In order to decide upon the level of foresight of business firms (i.e. is employment growth an exogenous event?..), we note here that qualitative empirical work (interviews and questionnaires) may be informative.

7 Conclusion

We have presented some preliminary investigations of a regression framework that, hopefully, will allow us to better understand the growth behaviour of business firms. The application of a VAR framework to firm growth has been introduced here, and we have investigated the robustness of our results along a number of dimensions, but our analysis should be seen as preliminary. In particular, there is a considerable degree of multicollinearity between the individual statistical series that make up the PVAR model, and this seems to make our results rather 'wobbly'. We are therefore wary of putting too much confidence in any specific point estimates.

We can identify (at least) three important caveats in our analysis.

First, despite our efforts to conduct a robustness analysis, there are still unresolved issues of sample selection bias that stem from the fact that we have not included firms with negative values for their gross operating surplus. Furthermore, our results are obtained from analyzing a balanced panel of surviving firms and does not deal with entry or exit.

Second, we observe that the R^2 statistics are rather low (typically lower than 5%). Could this be due to measurement error, aggregation effects, or perhaps due to some statistical fallacy? How does the R^2 improve when we include contemporaneous effects or longer lags? Does the R^2 statistic improve when we use data covering shorter time periods (e.g. quarterly data)? This issue clearly deserves to be explored.

Third, we do not know to what extent our results are specific to the case of French manufacturing firms.

A next step would be to begin thinking about moving from a reduced-form VAR to a structural VAR, in which some of the contemporaneous relationships are presented in more detail. If anything, our results would inform a structural VAR in which profits growth at (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.

One unresolved question concerns how we should aggregate over firms. Our results seem to suggest that, at the firm-level, employment growth precedes sales growth, and sales growth is associated with subsequent growth in profits. At the aggregate level, however, there is some evidence (from monthly US data) that increases in output are followed by a less than proportionate increase in labour hours, and that this increase occurs mostly within a 6-month interval (Sims, 1974).

We also outline some directions for future research. It may be fruitful to use data at quarterly intervals, in line with macroeconomic applications of VAR models. The Compustat database provides quarterly data on sales, investment, and other series and may be a suitable database in this respect. Furthermore, series such as R&D expenditure could be added to the VAR model. These would give additional information on the relationship between innovation and firm growth.[13] In addition, we might want to include investment in fixed assets in our VAR framework, even though there are specific issues related to this variable that would have to be dealt with.[14]

[13]One hypothesis we could test here (recently put forward by Giovanni Dosi) is that firms have 'behavioural' decision rules for R&D expenditures, whereby they make no attempt to 'maximize expected return on all future innovation opportunities', as some neoclassical economists might suggest, but instead they simply try to adjust their R&D expenditures in an attempt to keep a roughly constant R&D/sales ratio. This line of research is currently being pursued with Rekha Rao.

[14]First, there are problems distinguishing between expansionary and replacement investment, which obscures the relationship between investment in fixed assets and firm growth. Second, there is a remarkable lumpiness in the time series of investment in fixed assets. For example, Doms and Dunne (1998) consider a large sample of US manufacturing plants 1972-1988 and observe that, on average, half a plant's total investment was performed in just three years.

References

Alchian, A. A. (1950). Uncertainty, evolution and economic theory. *Journal of Political Economy*, 58:211–222.

Azevedo, J. P. W. (2004). grqreg: Stata module to graph the coefficients of a quantile regression. Technical report, Boston College Department of Economics.

Binder, M., Hsiao, C., and Pesaran, C. H. (2005). Estimation and inference in short panel vector autoregressions with unit roots and cointegration. *Econometric Theory*, 21:795–837.

Blundell, R. and Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 87:115–143.

Bottazzi, G., Cefis, E., and Dosi, G. (2002). Corporate growth and industrial structure: Some evidence from the italian manufacturing industry. *Industrial and Corporate Change*, 11:705–723.

Bottazzi, G., Coad, A., Jacoby, N., and Secchi, A. (2005). Corporate growth and industrial dynamics: Evidence from french manufacturing. Pisa, Sant'Anna School of Advanced Studies, LEM Working Paper series 2005/21.

Bottazzi, G., Dosi, G., Lippi, M., Pammolli, F., and Riccaboni, M. (2001). Innovation and corporate growth in the evolution of the drug industry. *International Journal of Industrial Organization*, 19:1161–1187.

Bottazzi, G., Secchi, A., and Tamagni, F. (2006). Productivity, profitability and financial fragility: evidence from italian business firms. Pisa, Sant'Anna School of Advanced Studies, LEM Working Paper series 2006/08.

Brouwer, E., Kleinknecht, A., and Reijnen, J. O. N. (1993). Employment growth and innovation at the firm level: an empirical study. *Journal of Evolutionary Economics*, 3:153–159.

Coad, A. (2005). Testing the principle of 'growth of the fitter': the relationship between profits and firm growth. Dept. of Economics Working Paper 05-31, Emory University, Atlanta GA.

Coad, A. (2006). A closer look at serial growth rate correlation. Pisa, Sant'Anna School of Advanced Studies, LEM Working Paper series 2006/29.

Coad, A. (2007). Firm growth: A survey. Papers on Economics and Evolution 2007-03, Max Planck Institute of Economics, Evolutionary Economics Group.

Delmar, F., Davidsson, P., and Gartner, W. B. (2003). Arriving at the high-growth firm. *Journal of Business Venturing*, 18:189–216.

Doms, M. and Dunne, T. (1998). Capital adjustment patterns in manufacturing plants. *Review of Economic Dynamics*, 1:409–429.

Dosi, G. (2007). *Perspectives on Innovation*, chapter Statistical Regularities in the Evolution of Industries: A Guide through some Evidence and Challenges for the Theory. Cambridge University Press.

Friedman, M. (1953). *Essays in Positive Economics*, chapter The Methodology of Positive Economics, pages 3–43. University of Chicago Press, Chicago, IL.

Geroski, P. A. (2000). *Competence, Governance and Entrepreneurship*, chapter The growth of firms in theory and practice, pages 168–186. Oxford University Press, Oxford, UK.

Koenker, R. and Hallock, K. F. (2001). Quantile regression. *Journal of Economic Perspectives*, 15(4):143–156.

Moneta, A. (2005). Causality in macroeconometrics: some considerations about reductionism and realism. *Journal of Economic Methodology*, 12(3):433–453.

Nelson, R. R. and Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. Belknap Press of Harvard University Press, Cambridge, MA.

Nickell, S. (1981). Biases in dynamic models with fixed effects. *Econometrica*, 49(6):1417–1426.

Pavitt, K. (1984). Sectoral patterns of technical change: towards a taxonomy and a theory. *Research Policy*, 13:343–375.

Penrose, E. T. (1959). *The Theory of the Growth of the Firm*. Basil Blackwell, Oxford.

Stock, J. H. and Watson, M. W. (2001). Vector autoregressions. *Journal of Economic Perspectives*, 15(4):101–115.