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Heterogeneous Effects of Monetary Policy

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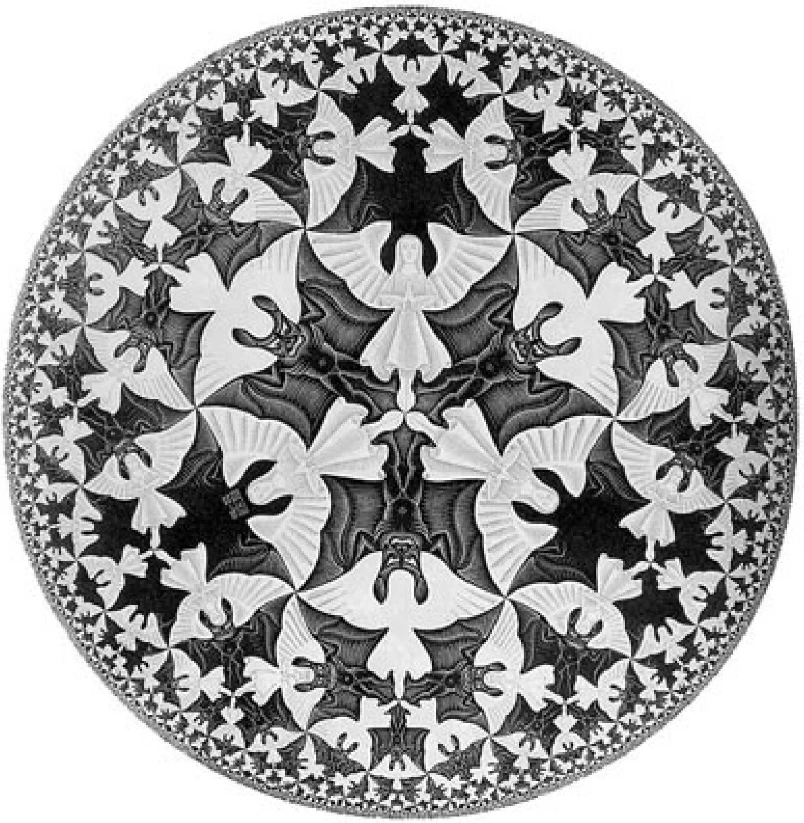
Heterogeneity



Circle Limit IV (aka Angels and Devils)
M.C. Escher

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Chapter 1

Introduction

The main objective of this thesis is to provide theoretical underpinnings and new empirical evidence in support of the hypothesis that differences in firms' balance sheet structures may generate heterogeneous responses to monetary policy impulses.

To this end, in the second chapter we start providing an assessment of the degree of heterogeneity among the balance sheet structures of manufacturing firms belonging to different European countries and different size classes. The comparison of the permanent components of these balance sheets, that have been obtained disentangling trend from cyclical factors, has allowed to obtain an evaluation of the degree of heterogeneity that is robust to business cycle effects that might be different across countries and across different size groups. This analysis is complemented, in the second part of the chapter, with an evaluation of the differences in the sensitivity to business cycle conditions of the balance sheet structures of firms that belong to different countries and different size classes. As frequently pointed out in the literature we also find that, independently of the size and the geographical location of the firm, inventories, commercial credit and commercial debt appear to be the most volatile items of the balance sheet. However significant heterogeneities in the relative importance of each of these items in shaping overall balance sheet dynamics emerge both across countries and across size classes.

In the third chapter we focus on a specific channel through which heterogeneities in the balance sheet structure might induce different responses to monetary policy innovations. In particular we address the existence of a channel of transmission of monetary policy, the cost-channel, that operates through the effect of interest expenses on the marginal cost of production. Such a channel is based on an active role of net working capital (inventories, plus trade receivables, less trade payables) in the production process and on the fact that variations in interest rates and credit conditions alter firms' short-run ability to produce final output by investing in net working capital. It has been argued that this mechanism may explain the dimension of the real effects of monetary policy, give a rationale for the positive short-run response of prices to increases in the interest rates (the "price puzzle") and call for a more gradual monetary policy response to shocks. The analysis is based on a unique panel, that includes data on individual prices and interest rates paid on several types of debt, for a sample of about 2000 Italian manufacturing firms over the period 1986-2000. We find robust evidence in favor of the presence of a cost-channel of monetary policy transmission, proportional to the amount of working capital held by each firm and with a size large enough to have non-trivial monetary policy implications.

The empirical analysis of chapter three is based on the hypothesis that the type of heterogeneity that produces different firm level responses to a change in interest rates (differences in the amount of working capital) is informed by theory. On the contrary, most of the empirical literature that tests for the existence of heterogeneous effects of monetary policy on firms' production or investment choices is based on *ad hoc* assumptions about the specific characteristic that should distinguish more sensitive from less sensitive firms.[1] The same degree of arbitrariness is adopted in selecting the number of groups of firms characterized by different responses to monetary policy shocks as well as in the selection of the cutoff points.[2] The objective of chapter four is to apply an econometric methodology that building on data predictive density, provides a well defined criteria to detect both the "optimal" number of groups and the "optimal" splitting points when firms are partitioned according to their sensitivity to monetary policy innovations. The empirical analysis is focused on Italian manufacturing firms and, in particular, on the response of inventory investment to monetary policy impulses from 1983 to 1998. The main results are the following. In strike contrast with what is normally assumed in the literature in most of the cases it turns out that the optimal number of groups is larger than two. Moreover orderings that are based on variables that are normally thought to be equivalent proxies for the size of the firm (i.e. turnover, total assets and level of employment) do not lead neither to the same number of groups nor to similar splitting points. Finally, even if endogenous clusters are mainly characterized by different degrees of within group heterogeneity, with groups composed by smaller firms showing the largest dispersion, there also exist important differences in the average

[1] Very common examples of these characteristics are the dimension, the leverage or the credit rating.

[2] Most of the empirical analysis available in the literature assumes the existence of two classes of firms (e.g. small and large or leveraged and unleveraged or those with a good and those with a poor credit rating).

effect of monetary policy across groups. In particular the fact that some of the orderings do not show the expected monotonicity between the rank and the average effect of monetary policy on inventories appears to be one of the most remarkable aspects.

Chapter 2

How Much Heterogeneity in European Balance Sheet Structures ?

2.1 Introduction

Since the seminal work of Modigliani and Miller (1958) thousands of pages have been spent to shed shiner light on the theoretical underpinnings that rationalize the composition of the balance sheet structure of the firm.[1] Unquestionable achievements notwithstanding, many aspects of this field still remain coiled by a curtain of darkness and, consequently, this area of research continues to be one of the most prolific grounds for fierce academic disputes. Developments in the empirical literature have reflected those of the theoretical counterpart and have proliferated in an extensive amount of valuable results. According to Harris and Raviv (1991) this literature can be categorized into four classes: event studies, intra-sectoral studies, inter-sectoral analysis and international comparisons. While the first class is mainly focused on specific aspects of the balance sheet structure like the effectiveness of corporate restructuring in cases of hostile takeovers, the remaining classes are composed of analysis that aim at identifying the specific characteristics of firms and industries that can be seen as the principal causes for differences in the balance sheet structure. The works of Rajan and Zingales (1995), Corbett and Jenkinson (1996), Frankel and Montgomery (1991) and Borio (1990) are some of the most well know examples of this field of research. Until the end of the eighties most of these analysis were focused on U.S. data because European dataset, when available, were strongly affected by reliabil-

[1] Most of the principal results are summarized in the work of Harris and Raviv (1991).

ity and comparability problems. These problems were particularly hurting the European Commission since the lack of reliable and comparable data on the balance sheet structure of firms belonging to different European countries was substantially affecting the possibility of individuating and solving problems that could have affected the convergence of the different European countries toward the EMU. For this reason the European Commission has decided to construct a representative and harmonized dataset of the balance sheet structures of European firms. This dataset has been extensively used to analyze very disparate topics including fixed capital and inventories investment, production and growth. Of course part of these researches have also focused on the comparison of balance sheet ratios across different types of firms. Among the most recent examples of this last type of analysis there are the works of Rivaud Danset, Salais and Dubocage (2001) and Coeurderoy (2000). While the main objective of Rivaud Danset et al. (2001) is to search for differences between small, medium and large firms in terms of profitability and flexibility, the study of Coeurderoy (2000) focuses on the identification of the determinants of leverage ratios. However more comprehensive studies are rare. This is particularly surprising since the relevance of a widespread analysis was already pointed out many years ago by Rondi, Sembenelli, Schiantarelli and Sack (1998)[2]. *"Whereas a fair amount is known about (the effects of) cyclical fluctuations (on balance sheet structures) in the US, little evidence is available on these issues for other countries...Moreover, even for the US most of the results concern, on the financial side, the behavior of bank lending and of commercial paper and, on the real side, sales and inventories. What is necessary is a more complete analysis that includes the cyclical response of trade credit received and of short term financial assets (including trade credit given)...Finally the analysis of the behavior of short run investment (like inventory accumulation) must be conducted jointly with the analysis of how the response of fixed investment to financial factors varies over time for different types of firms"*. To the best of our knowledge only the work of Debreil (2000) has made a step toward this goal by providing, on a year by year basis, means and medians of a large number of balance sheet items and by discussing similarities and differences among these statistics for firms belonging to different size classes and different countries. Our analysis shares the spirit of Debreil (2000). However instead of focusing on the comparison of basic descriptive statistics computed on raw data, we center on the comparisons of structural components of the items of the balance sheet

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[2] Rondi et al. (1998) use a database from Mediobanca, a leading Italian bank, to estimate the sensitivity of different balance sheet items of Italian manufacturing firms to variations in the monetary policy stance.

that have been obtained regressing raw data on a constant and a trend. This approach has the advantage to clean out part of the noise in the raw data and, secondly, allows us to get rid of the risks induced by non synchronized business cycles when we compare balance sheet structures in different countries. In the second part of the chapter we complement this analysis with an evaluation of the sensitivity to business cycle fluctuations of the different items of the balance sheet. Also in this case after having computed measures of the relative contribution of the components of the balance sheet in determining the overall volatility of the balance sheet we look for similarities and differences among firms belonging to different countries and different size classes.

2.2 The Dataset: BACH

The data used in this research are obtained from the BACH database managed by the European Commission.[3] The database was set up in 1987 with the idea of providing managers, investors and researchers with harmonized information on the balance sheet structure of the industrial sectors of the different European countries. Information sources were already existing at national levels and the main tasks of the Committee have been to develop a common layout for accounting harmonization[4] and to construct transition tables to convert national data into a unique framework. The principal goal of the harmonization work of the European Committee of Central Balance Sheet Data Offices was therefore to eliminate known differences as far as possible, to identify remaining differences and to provide tools to appropriately interpret these differences in financial analysis. BACH contains harmonized annual accounts statistics for the industrial sector of 11 European countries plus Japan and the United States. Balance sheet and profit and loss data are not available at a firm-level but, instead, have been aggregated into 23 sectors or sub-sectors[5] and, within each of them, into three classes related to the size of the firm[6]. For each group of firms belonging to a given size class and to a given sub-sector yearly time series going back to 1982 are

[3]The database is managed and distributed by the Directorate-General for Economic and Financial Affairs of the European Commission. This database has been developed in co-operation with the European Committee of Central Balance Sheet Data Offices (ECCB).

[4]The common layout is based on Articles 10 and 23 of the 4th Council Directive.

[5]In particular the manufacturing sector is disaggregated up to a 3-digit NACE level.

[6]Firms are defined as "small" if their net turnover is smaller than 7 millions of euro, "medium" if the net turnover is between 7 and 40 millions of euro and "large" if their net turnover is greater than 40 millions of euro.

available for approximately one hundred items of the balance sheet and of the profit and loss account. Due to data availability and to the existence of major differences between the information provided for European countries on one side and United States and Japan on the other, we restrict ourselves to France, Germany, Italy and Spain.[7] Moreover, for comparability reasons, we limit the analysis to the manufacturing sector. The lists of the sub-sectors and of the balance sheet items that we analyze in this work are presented in Tables 2.1 to 2.3.

Table 2.1: Manufacturing: NACE 3-digit Sub-sectors

NACE code	*Description*
21	*Intermediate*
211	Extraction of metalliferous ores
212	Extraction of non-metalliferous ores
213	Chemicals and man-made fibers
22	*Durables*
221	Metal articles
222	Electrical and electronic equipment
223	Manufacture of transport equipment
23	*Non Durables*
231	Food, drink and tobacco
232	Textiles, leather and clothing
233	Timber and paper manufacture
234	Manufacturing (others)

The structure of the dataset is therefore a panel composed by the variables described in Tables 2.2 and 2.3 and with each of them characterized by four indexes (c, s, d, t) where c stands for *Country*, s for *Sector*, d for *Dimension* (Size) and t for *Time*. Each individual observation reports the sum of the nominal value of a specific balance sheet item for all the firms that belong to the same country, sector, size class in a given year. The comparison of the main characteristics of BACH with those of the other datasets usually adopted for this type of analysis (e.g. Compustat, Datascope and Global Vintage) let emerge some important differences. First, a major advantage in using information obtained from BACH is the fact that data have been reclassified according to a common rule. The lack of harmonization makes comparisons based on data obtained from other datasets very difficult

[7]Data for Italy and Spain are available for the sample time 1982-1997, those for France for the period 1984-1997 and those for Germany for the sample 1987-1996.

Table 2.2: Balance Sheet Items: Assets

Description
Subscribed capital unpaid
Fixed Assets
Intangible fixed assets
Tangible fixed assets
Financial fixed assets
Current assets
Stocks
Trade debtors
Other debtors
Current Investment
Cash at bank and in hand
Prepayments and accrued income

and limited. A second advantage of BACH is the fact that it includes also very small enterprises. This is normally not the case for other international datasets that are constructed just with quoted, and therefore larger, firms. Another specific characteristic of BACH is the fact that it is aggregated at a sub-sector level and according to size classes. There are two main advantages in using data that are aggregated according to these criteria. The first one is the fact that aggregation should reduce noise in the data, the second one the fact that the groups can be expected to be homogeneous along time, since if a firm passes the size-threshold it is moved to the next class. This last aspect is fundamental to preserve the nature of the group, or, to say it in another way, it allows to properly disentangle changes related to the growth of the firm from changes related to structural variations in the balance sheet characteristics of specific size-classes. One problem, that has nothing to do with the level of aggregation of the data, but that might significantly influence the results of the analysis is related to the possibility of sampling biases. These could be particularly relevant for French and Spanish data, since in these countries information on the balance sheet are collected on a voluntary basis, and in data related to small firms that are well known to be underrepresented in BACH.[8] The most likely source of the bias is the fact that only "successful" good small and medium firms are represented in our dataset. The main implication of this is that our results cannot be interpreted as the difference between large, medium and small firms but as the difference

[8]For more detailed informations on the representativeness of BACH refer to EC (2000).

Table 2.3: Balance Sheet Items: Liabilities

Description
Liabilities due in one year
Amounts owed to credit institutions
Payments received on account of orders
Trade creditors
Other financial creditors
Other non-financial creditors
Liabilities due more than one year
Debenture loans
Amounts owed to credit institutions
Trade creditors
Other financial creditors
Other non-financial creditors
Provisions for liabilities and charges
Accruals and deferred income
Capital and reserves
Subscribed capital
Share premium account
Revaluation reserve
Reserves
Profit or loss brought forward
Profit or loss for the financial year

between large enterprises and ”successful” medium and small enterprises.

2.3 Comparative Static and Trends

The objective of this section is to compare the balance sheet structure of different groups of firms obtained aggregating the data from BACH according to the nationality and the size of the productive unit. Even if we have decided to restrict ourselves to the comparison along these two dimensions we are perfectly aware of the fact that one more level of disaggregation, that is the distinction between firms that belong to the intermediate, the durable and the non-durable sector, would produce a more valuable insight on the heterogeneity of balance sheet structures. Unfortunately time series disaggregated at a sectoral level proved to be too strongly affected by measurement errors and/or idiosyncratic shocks to be useful in providing reliable results.

For this reason the analysis of this section has been limited to a level of disaggregation based on size and nationality. To perform a comparison that is not affected by cyclical components that may be different across countries and, possibly, also across different size classes, we have decided to focus on the structural components of the balance sheets that have been obtained regressing raw data on a constant term and a trend. The estimated parameters and the fitted values of these regressions have subsequently been used to obtain an assessment of degree of heterogeneity in the trends and in the end of sample levels of the balance sheet structures of different groups of firms. The main result of this section is the fact that a large degree of heterogeneity still persists even if one controls for the effect of business cycle dynamics.

2.3.1 Data Transformation and Estimation Methodology

Given the nature of the observations that constitute our dataset[9] an analysis that focuses on nominal values is not recommendable since the results would be strongly affected by the fact that the number of firms in a given group (i.e. a "country - sector - size" class) changes along time. Similarly the use average nominal levels would not provide valuable insights since it would not allow to disentangle real from nominal variations. As it is customary in this branch of the literature we have therefore decided to work with balance sheet ratios. In particular we have divided all the items of the balance sheet of a given group of firms in a given year by the corresponding nominal value of net turnover. The balance sheet ratio adopted has a direct economic interpretation, that is it represents the value of a balance sheet item that is necessary to produce a unit (of money) of sales in a given year and constitutes a valid measure to perform comparison among levels and trends of balance sheet ratios of different groups of firms.[10] As stated in the introduction, the two main tasks of this section are cross-country, cross-size comparisons of the levels and the trends of the balance sheet ratios. As far as comparative static is concerned one of the principal problems we have to take into account is

[9]Each individual observation reports the sum of the nominal value of a specific balance sheet item for all the firms that belong to the same "country - sector - size" class in a given year.

[10]We have investigated also the possibility of dividing balance sheet items by total assets. This possibility has been discarded since, by dividing all the items of the balance sheet by total assets, one incurs the risk of inducing uninformative trends. This risk is particularly relevant for our dataset since from the beginning of the eighties to the late nineties financial fixed assets have shown spectacular positive growth rates. Such an increase, by inflating the value of total assets, would induce negative growth rates in most of the other ratios.

the possibility of international heterogeneities in the business cycle and the possibility of heterogeneities in the sensitivity to business cycle fluctuations of balance sheet items of firms belonging to different size classes. To control for business cycle components we have regressed all the ratios on a trend and we have focused the analysis on fitted values. In particular we have run a set of regressions according to the following specification:

$$x^i_{c,s,d,t} = \alpha_{c,sm} + \alpha_{c,me} + \alpha_{c,la} + \beta_{c,sm}t_{c,sm} + \beta_{c,me}t_{c,me} + \beta_{c,la}t_{c,la} + +\epsilon^i_{c,s,d,t} \quad (2.1)$$

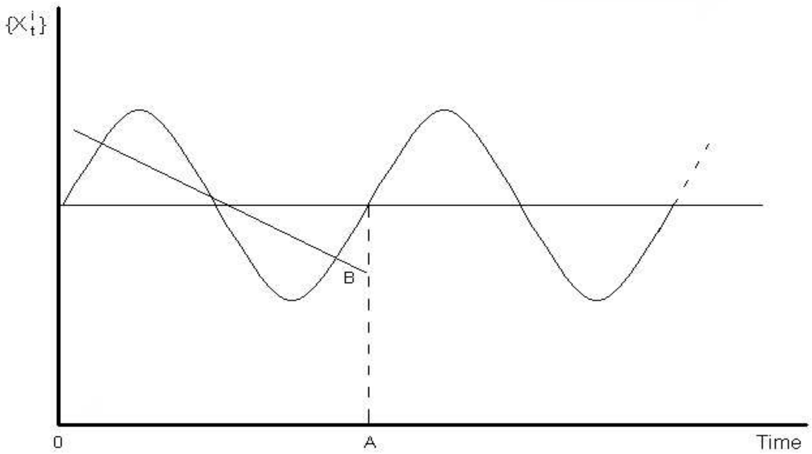
where $x^i_{c,s,d,t}$ is the balance sheet ratio for item i, country c, sector s, dimension (size) d at time t, $\alpha_{c,d}$ (d either small, medium or large) is a country and dimension specific constant term, $\beta_{c,d}$ is a country and dimension specific trend parameter and $\epsilon^i_{c,s,d,t}$ is a residual that includes cyclical components plus an iid shock.[11] This specification has been preferred to the one that includes also a quadratic trend according to a "parsimoniousness criterion" since the inclusion of the quadratic trend did not improved significantly the goodness of the fit and to models that directly specifies cyclical components by including, for example, lagged terms of the dependent variable as regressors because of the excessive sensitivity of the estimated parameters to the choice of the estimation methodology and the set of instruments.[12] Before running our regressions we have removed outliers following the methodology proposed by Hadi (1992) and Hadi (1994) that is based on a opportune transformation of the Mahalanobian distance of the data and has been proved to be one of the best methods available to control for swamping and masking effects. Moreover, given that our specification includes only a constant term and a trend we have verified to what degree we could expect that the combination of a small sample period with the cyclicality that characterizes our data was likely to induce spurious trends. The intuition of the problem is presented in figure 2.1.

Figure 2.1 depicts a deterministic cyclical time series with no trend. If we assume to observe realizations only for the sample period from *"0"* to *"A"* and to regress these realizations on a constant term and a trend we would obtain a fitted line qualitatively similar to *"B"*. This implies that we

[11] Due to the limited temporal size of the dataset the analysis based on an higher level of disaggregation (i.e. estimates disaggregated also according to the sector of origin) did not provide a sufficiently large number of significant estimates and, therefore, had to be discarded. This formulation allows to take into account possible within country, within time, within size correlation in the error terms.

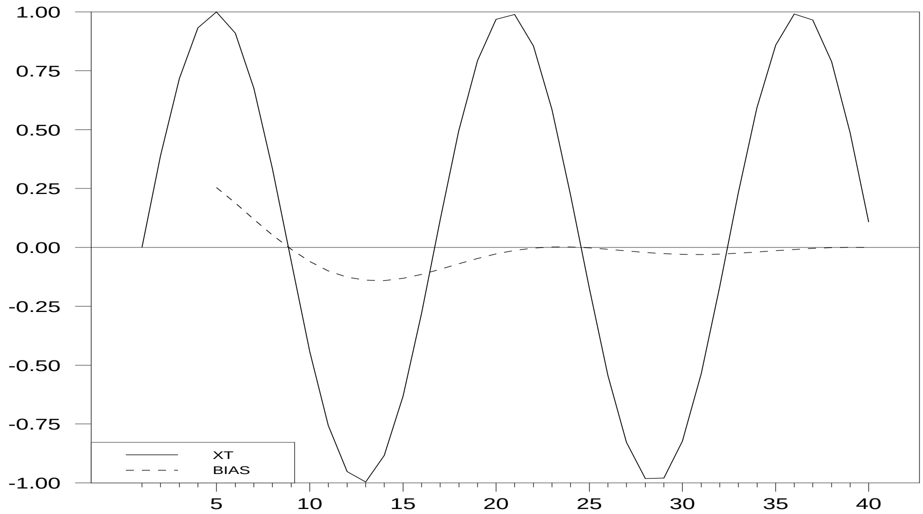
[12] We have evaluated fixed effect and random effects models as well as the methodology proposed by Anderson and Hsiao (1981), Arellano (1989), Arellano and Bond (1991) and Arellano and Bover (1995).

Figure 2.1: Adverse Effects of a Too Short Sample Period.



would incorrectly estimate a negative growth rate even if the series is not characterized by such a feature. The bias in the estimated trend parameter is characterized by two main features: it goes to zero as the sample size increases and is cyclical itself. The bias, as a function of the sample size, for a series like the one described in figure 2.1 is shown in figure 2.2.

Figure 2.2: The Bias in the Estimation of the Trend as a Function of the Sample Size.



Since our sample period includes the expansion of the middle to late eighties, the recession of the early nineties, the expansion of the middle nineties and the beginning of the downturn of the late nineties (that is our series are expected to have a shape similar to the one depicted in figure 2.2 over the interval 0 to 25) we believe that the bias should be, if anything, very small.

2.3.2 Main Results

The results of the estimations are reported in tables 2.4 to 2.11. In these tables we present, for each item of the balance sheet, the fitted value of its net turnover ratio at the beginning and at the end of the sample and a measure of the implicit (average) annual growth rate.[13] The empirical evidence obtained through the econometric analysis is summarized in the remaining part of this section where we focus on the main similarities and the principal differences in the end of sample levels and in the trends of the balance sheet ratios of firms belonging to different countries and different size classes.

France

Asset side in 1996 (table 2.4): The total assets - net turnover ratio turns out to be the most important dimension of heterogeneity for firms belonging to different size classes. In 1996 this ratio was equal to 0.65 and 0.70 for, respectively, small and medium firms and to 0.90 for large firms. However this difference seems to be almost completely driven by a specific item, the amount of financial fixed assets hold by large firms. Leaving aside the contribution of this item generates a picture of closer similarity in the structure of the asset side of the balance sheet of firms belonging to different size classes with trade debtors, stocks and tangible fixed assets being the most relevant items. Yet tangible fixed assets appears to play a relatively less important role in the balance sheet structure of small firms in 1996. *Trends in the asset side*: One of the most important features is the fact that, compared with 1984, in 1996 French firms need a larger value of assets to generate 1 unit (of money) of output.[14] Another striking feature has been the significant increase in the financial fixed assets - net turnover ratio for large firms (from 0.08 to 0.22). Dynamics that have been common across firms are instead the decrease in the role played by stocks and the increase in the amount liquidity (defined as the sum of cash, current investment and other debtors)

[13] The average growth rate has been constructed as $\left(\frac{\hat{X}}{S}_{i,j,T} - \frac{\hat{X}}{S}_{i,j,0}\right) \Big/ \frac{\hat{X}}{S}_{i,j,0} \cdot \frac{100}{T}$.

[14] For example the total asset - net turnover ratio for large firms has increased, from 1984 to 1996, from 0.73 to 0.85.

Liability side in 1996 (table 2.5): The main difference between the liability structure of large firms, on one side, and that of small and medium firms, on the other is the role played by own capital and reserves that is substantially larger for the formers. Another difference is the fact that small and medium firms seems to be more dependent to credit institutions for long term fund raising while larger firms obtain it from other types of financial institutions. *Trends in the liability side*: One of the principal features that emerges if one compares the balance sheet structures at the beginning and at the end of the sample is the fact that large firms have substantially reduced their dependence from banks. The ratio between short and long term debts with banks and net turnover was around 0.15 in 1984 and has become 0.06 in 1996. This decline in the use of credit from banks has somehow affected also medium firms. Another characteristic is the generalized increase in the role played by capital and reserves for all the classes of firms and, in particular, for larger firms.

Germany

Asset side in 1995 (table 2.6): The asset side of the balance sheet structure of German firms belonging to different size classes shares many of the features observed for their French counterparts. Also in this case the total assets - net turnover ratio turns out to be the most important dimension of heterogeneity for firms belonging to different size classes. In 1996 this ratio was substantially greater for large firms (0.73) than for small and medium firms (respectively 0.56 and 0.51). This difference seems to be principally driven by the amount of financial fixed assets hold by large firms, as in the French case, and by the amount of credit provided by large firms to debtors that are not usual trade partners. Leaving aside these features provides a picture of substantial similarity in the structure of the asset side of the balance sheet of firms belonging to different size classes even if the role played by tangible fixed assets appears to be increasing with the size of the firm. *Trends in the asset side*: Differently from the French case there does not seem to be a strong trend in German total assets - net turnover ratios.[15] However large German firms share with their French counterparts the sharp increase in the relative amount of financial fixed assets and the significant contraction in the role played by stocks. Another characteristic that is worthwhile noticing is the significant increase in the amount of credit provided by all types of firms to debtors that are not usual trade partners.

Liability side in 1995 (table 2.7): The picture that emerges from the anal-

[15]This might partly reflect the smaller temporal sample.

ysis of the estimated ratios is characterized by the fact that the size of the firm is an inverse proxy for the financial duration of its liability side. In particular while short term debt accounts for more than fifty per cent of the liability side of small firms, this percentage is equal to around 45 per cent for medium firms and only 30 per cent for large firms. On the other side the role played by own capital and reserves ranges from the 68 per cent for large firms to slightly more than 50 per cent for small firms.[16] *Trends in the liability side*: As it was the case for the asset side, also the structure of the liability side of the balance sheet of German firms does not seem to be subject to important changes. If anything a slight increase in the role played by capital and reserves in the balance sheet of large firms has emphasized, with respect to 1984, the differences described in the previous paragraph.

Italy

Asset side in 1996 (table 2.8): In Italy the total assets - net turnover ratio is significantly larger than those observed for France and Germany and it does not seem to be substantially different across firms. This evidence seems to be due to the fact that Italian firms are characterized by a production process that makes a larger use of tangible fixed assets, stocks and trade credit. Another important difference with respect to the French and the German case is the fact that in Italy the relative weight of these three items is significantly larger for smaller firms. Finally, it is worthwhile noticing that also in Italy large firms are characterized by a more relevant amount of financial fixed assets. *Trends in the asset side*: As it was the case for France, also in Italy the total assets - net turnover ratio shows a strong increase from 1982 to 1996. However in Italy this trend does not seem to characterize large firms. As far as trends in the single items of the asset side are concerned four aspects are particularly interesting. First, as we have already seen for France and Germany, a substantial increase in financial fixed assets is a common feature across different size classes and, in particular, for large firms. However it is interesting to note that it is not as striking as in France and Germany. Second also in Italy there is a clear downward trend in the amount of stocks held by the manufacturing sector as a whole, again with a decrease that is more pronounced for large firms. Third, the trends in the relative importance of trade debtors are the same as in France and, to a lesser extent, also in Germany with an increase in the amount held by

[16] The important role played by provisions for liabilities and charges is due to the fact that, in Germany, funds to be used for pensions are partly accumulated by the government and partly by the employer.

small firms and a decrease in that of large firms. Finally, in 1996 all the size classes seem to allocate more resources in credit to non commercial partners than in 1982, a characteristic that is shared also with France and Germany.

Liability side in 1996 (table 2.9): Estimates of the liability ratios for Italian manufacturing firms do not let emerge a substantial differences in the relative weight of short term debts, long term debts and capital and reserves. However, while on one side smaller firms obtain most of their short term funds from credit institutions, larger firms seems to make a relatively smaller use of bank funds and to obtain more resources from other type of financial institutions. Even taking into account these differences the use of bank credit as a form of financing is, independently of the size class, substantially larger in Italy than in France and Germany. *Trends in the liability side*: The major trend that emerges from the comparison of the estimated balance sheet structure of 1982 with that of 1996 is that small and medium firms have increased their dependence from bank financing, while, on the other side, larger firms have reduced it in favor of other forms of external financing (using credit from other financial and non-financial creditors) and of own capital.

Spain

Asset side in 1996 (table 2.10): In 1996 the estimated total assets - net turnover ratios for Spanish firms are in between those of French and German firms and those of Italian firms. Also in Spain the three most important items of the asset side of the balance sheet are tangible fixed assets, stocks and trade debtors. However some differences emerge from the comparison of the structure of small, medium and large firms. In particular, as in the German case, the role played by tangible fixed assets is substantially more important in the balance sheet structure of larger firms while, on the other side, small firms make a relatively larger use of stocks, as in the Italian case. Once more the asset side of large firms is characterized by a larger amount of financial fixed assets. *Trends in the asset side*: The analysis of the temporal evolution of the items of the asset side suggests that from 1982 to 1996 there has been a strong contraction in the use of assets relatively to sales. This reduction has been particularly striking for large firms. Their total assets - net turnover ratio has decreased from around 1,21 to 0,95. A similar evidence, even if less striking, emerge from the analysis of the balance sheet structure of small and medium firms. Independently of the size of the firm the decrease in the total assets - net turnover ratio reflects the reduction in the use of tangible fixed assets, stocks and trade debtors. The fall in the use of tangible fixed assets and stocks has been particularly remarkable for large firms. Finally a significant increase in the relative use of financial fixed assets is again a common feature across different size classes and is particularly important for large firms.

Liability side in 1996 (table 2.11): The analysis of the liability side of the balance sheet structure of Spanish firms offers a pattern that is similar to those already observed for the other major European countries. The two main features that emerge from cross-size comparison are related to the role played by capital and reserves, that is substantially larger for larger firms, and the fact that small and medium firms obtain a relatively larger amount of short and long term credit from banks. *Trends in the liability side*: The reduction in the importance of short term debt in Spanish liability structures has been mainly driven by significant reductions in the level of indebtedness with banks and, to a lesser extent, by reductions in the level of exposure with other non financial creditors. The reduction in the level of indebtedness with banks for large firms is particularly striking since in 1984 this channel was providing almost 22% of total funding while, in 1996 it does not even reach 10%. As far as long term liabilities are concerned there is not a substantial change in the relative importance of the different items for small and medium firms while large firms show a steady decline in the amount of indebtedness with banks that is offset by an almost equivalent increase in the amount of provisions for liabilities and charges.

The main result that emerges from this analysis can be summarized as follows: even if the general picture is one of substantial homogeneity among the balance sheet structures of productive units belonging to different countries and different size classes the analysis suggests the presence of some important forms of heterogeneity. In particular the evidence presented in this section shows that the degree of heterogeneity observed along the size dimension (i.e. the more intensive use of tangible fixed assets, of financial fixed assets, of long term debt and of own funds by large firms with respect to smaller counterparts, as well as their more limited dependence on bank funds, just to make a few examples) is larger than that observed along the country dimension (that has emerged only through a more intensive use of tangible fixed assets, stocks and trade debt provided by Italian and Spanish firms with respect to their French and German counterparts). Moreover it has also been possible to detect a number of trends in the dynamic evolution of corporate structure. Some of them, like the strong increase in financial fixed assets, seem to be limited to firms belonging to a certain size class. Some others, like the decrease in the relative amount of trade credit provided by Spanish firms, seem to be country specific. Finally there exist some other trends, like the reduction in the amount of stocks, that are widespread across countries and size classes.

Table 2.4: Fitted Values and Trends of the Balance Sheet Ratios: France.
(values expressed in percentage points of Net Turnover)

	Assets								
	Small			*Medium*			*Large*		
	1984	1996	growth[(a)]	1984	1996	growth[(a)]	1984	1996	growth[(a)]
Subscribed capital unpaid	0.01	0.01	2.42	0.01	0.02	5.72	0.08*	0.00	-8.69*
Intangible fixed assets	0.51*	1.68	19.27*	0.49*	1.11	10.68*	0.47*	1.25	13.84*
Tangible fixed assets	11.11*	11.76	0.49	12.16*	14.04	1.29	15.47*	16.98	0.81
Financial fixed assets	1.58*	2.34	4.00	2.54*	4.12	5.21	8.18*	21.62	13.68*
Stocks	15.98*	14.45	-0.80*	18.15*	15.23	-1.34*	18.34*	14.38	-1.80*
Trade debtors	20.79*	21.31	0.21	22.25*	22.59	0.13	23.02*	20.36	-0.96*
Other debtors	2.92*	4.32	3.98*	3.45*	4.89	3.46*	4.80*	8.54	6.48*
Current Investment	0.90*	3.74	26.36*	0.65*	2.96	29.43*	1.42*	3.13	10.00*
Cash at bank and in hand	3.59*	4.22	1.46*	2.84*	3.73	2.61*	3.20*	2.58	-1.62*
Prepayments and accrued income	0.46*	0.85	7.04*	0.50*	0.81	5.22*	0.65*	0.77	1.49*
Total assets	57.85	64.69	0.98	63.04	69.50	0.85	75.65	89.61	1.54

Fitted values and trends presented in this table are based on equation 2.1. A (*) in the "1984" columns denotes that the estimated constant term $(\widehat{\alpha}_{c,d})$ is significant at the 5% confidence level. A (*) in the "growth" columns denotes that the estimated trend parameter $\left(\widehat{\beta}_{c,d}\right)$ is significant at the 5% confidence level. Beginning of period and end of period values for "Total assets" are computed as the sum of the estimated values of each of the items available.
[(a)] Average annual growth rate as defined at the beginning of subsection 2.3.2.

Table 2.5: Fitted Values and Trends of the Balance Sheet Ratios: France.
(values expressed in percentage points of Net Turnover)

	Liabilities								
	Small			*Medium*			*Large*		
	1984	1996	growth[(a)]	1984	1996	growth[(a)]	1984	1996	growth[(a)]
Amounts owed to credit institutions	3.82*	3.39	-0.93	6.17*	4.04	-2.88*	6.75*	3.12	-4.48*
Payments received on account of orders	0.32*	0.25	-1.82	0.26*	0.31	1.69	0.37*	0.27	-2.14
Trade creditors	16.29*	15.52	-0.40	15.95*	15.84	-0.06	14.33*	14.63	0.17
Other financial creditors	0.26*	0.17	-2.94	0.23*	0.53	10.63*	0.52*	1.53	16.30*
Other non-financial creditors	8.65*	8.27	-0.37	7.77*	7.06	-0.76	7.80*	7.72	-0.08
Debenture loans	0.13	0.08	-3.29	0.22	0.14	-2.92	2.11*	1.13	-3.86*
Amounts owed to credit institutions	6.23*	6.20	-0.05	6.64*	5.36	-1.61*	8.58*	3.11	-5.31*
Trade creditors	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Other financial creditors	4.84*	5.11	0.46	5.19*	5.59	0.65	8.36*	10.45	2.09*
Other non-financial creditors	0.46*	0.37	-1.64	0.79*	0.61	-1.93*	1.02*	0.89	-1.10
Provisions for liabilities and charges	1.02*	1.28	2.09	1.71*	1.85	0.71	3.96*	5.44	3.12*
Accruals and deferred income	0.15*	0.22	4.11	0.11	0.14	2.95	0.51*	0.54	0.39
Subscribed capital[(b)]	5.57*	8.67	4.63*	6.43*	11.41	6.45*	9.16*	18.97	8.92*
Revaluation reserve	0.18*	0.08	-4.77*	0.21*	0.11	-3.83*	0.47*	0.13	-5.97*
Reserves	8.87*	14.59	5.38*	8.80*	13.24	4.21*	8.51*	12.46	3.87*
Profits or losses[(c)]	0.93*	1.12	1.72	0.89	3.04	20.19*	0.77	4.82	44.10*
Total liabilities	57.72	65.31	1.10	61.35	69.26	1.07	73.21	85.21	1.37

Fitted values and trends presented in this table are based on equation 2.1. A (*) in the "1984" columns denotes that the estimated constant term $(\widehat{\alpha}_{c,d})$ is significant at the 5% confidence level. A (*) in the "growth" columns denotes that the estimated trend parameter $\left(\widehat{\beta}_{c,d}\right)$ is significant at the 5% confidence level. Beginning of period and end of period values for "Total liabilities" are computed as the sum of the estimated values of each of the items available.

[(a)] Average annual growth rate as defined at the beginning of subsection 2.3.2.
[(b)] Subscribed capital and share premium account.
[(c)] Profit or losses for the financial year and brought forward.

Table 2.6: Fitted Values and Trends of the Balance Sheet Ratios: Germany.
(values expressed in percentage points of Net Turnover)

	Assets								
	Small			*Medium*			*Large*		
	1987	1995	growth[(a)]	1987	1995	growth[(a)]	1987	1995	growth[(a)]
Subscribed capital unpaid	0.18*	0.10	-5.69*	0.10*	0.08	-2.14	0.04*	0.04	1.75
Intangible fixed assets	0.33*	0.58	9.25*	0.50*	0.79	7.16*	0.29	0.70	17.33*
Tangible fixed assets	13.48*	13.59	0.11	14.94*	15.45	0.43	18.13*	17.70	-0.30
Financial fixed assets	1.90*	2.01	0.73	2.59*	3.89	6.29	9.45*	15.75	8.34*
Stocks	14.96*	14.68	-0.23	16.15*	15.02	-0.88	16.86*	13.85	-2.23*
Trade debtors	10.33*	10.43	0.12	10.02*	10.10	0.11	8.92*	8.53	-0.54
Other debtors	4.61*	6.78	5.90*	5.36*	7.56	5.13*	9.31*	12.70	4.56*
Current Investment	0.07	0.12	9.73	0.21	0.22	0.57	1.84*	1.08	-5.16*
Cash at bank and in hand	3.07*	3.27	0.84	2.93*	2.98	0.21	3.64*	3.21	-1.48
Prepayments and accrued income	0.33*	0.36	0.98	0.22*	0.26	2.16	0.16*	0.15	-0.83
Total assets	49.25	51.92	0.68	53.02	56.36	0.79	68.64	73.72	0.92

Fitted values and trends presented in this table are based on equation 2.1. A (*) in the "1987" columns denotes that the estimated constant term $(\widehat{\alpha}_{c,d})$ is significant at the 5% confidence level. A (*) in the "growth" columns denotes that the estimated trend parameter $\left(\widehat{\beta}_{c,d}\right)$ is significant at the 5% confidence level. Beginning of period and end of period values for "Total assets" are computed as the sum of the estimated values of each of the items available.
[(a)] Average annual growth rate as defined at the beginning of subsection 2.3.2.

Table 2.7: Fitted Values and Trends of the Balance Sheet Ratios: Germany.
(values expressed in percentage points of Net Turnover)

	Liabilities								
	Small			*Medium*			*Large*		
	1987	1995	growth[a]	1987	1995	growth[a]	1987	1995	growth[a]
Amounts owed to credit institutions	6.69*	8.28	2.99*	5.79*	6.76	2.10*	2.70*	3.48	3.61
Payments received on account of orders	1.08*	1.05	-0.33	0.65*	0.78	2.35	0.20	0.24	2.25
Trade creditors	9.50*	8.39	-1.47*	7.82*	7.23	-0.93	5.63*	5.36	-0.59
Other financial creditors	7.44*	9.20	2.96*	8.23*	9.85	2.45*	7.41*	11.56	7.01*
Other non-financial creditors	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Debenture loans	0.00	0.00	-3.58	0.03	0.01	-7.03	0.22*	0.12	-5.62*
Amounts owed to credit institutions	6.31*	7.64	2.63*	4.92*	5.87	2.43	3.71*	2.76	-3.20
Trade creditors	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Other financial creditors	3.19*	3.28	0.32	2.49*	2.47	-0.06	2.27*	2.16	-0.57
Other non-financial creditors	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Provisions for liabilities and charges	6.17*	6.84	1.37	9.05*	9.92	1.20	20.68*	22.94	1.37
Accruals and deferred income	0.05*	0.06	0.86	0.04*	0.05	3.22	0.04*	0.05	2.11
Subscribed capital[b]	5.36*	5.13	-0.53	8.37*	9.19	1.23	13.47*	18.42	4.59*
Revaluation reserve	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Reserves	1.04*	1.27	2.76	2.83*	2.67	-0.72	6.00*	6.32	0.66
Profits or losses[c]	2.38*	1.19	-6.23*	2.11*	1.21	-5.36	2.14*	1.45	-4.01
Total liabilities	49.22	52.34	0.79	52.33	56.02	0.88	64.45	74.86	2.02

Fitted values and trends presented in this table are based on equation 2.1. A (*) in the "1987" columns denotes that the estimated constant term $(\widehat{\alpha}_{c,d})$ is significant at the 5% confidence level. A (*) in the "growth" columns denotes that the estimated trend parameter $\left(\widehat{\beta}_{c,d}\right)$ is significant at the 5% confidence level. Beginning of period and end of period values for "Total liabilities" are computed as the sum of the estimated values of each of the items available.

[a] Average annual growth rate as defined at the beginning of subsection 2.3.2.

[b] Subscribed capital and share premium account.

[c] Profit or losses for the financial year and brought forward.

Table 2.8: Fitted Values and Trends of the Balance Sheet Ratios: Italy.
(values expressed in percentage points of Net Turnover)

	Assets								
	Small			*Medium*			*Large*		
	1982	1996	growth[(a)]	1982	1996	growth[(a)]	1982	1996	growth[(a)]
Subscribed capital unpaid	0.14*	0.08	-3.03*	0.07*	0.05	-2.22	0.01	0.01	5.15
Intangible fixed assets	1.68*	2.59	3.90*	1.17*	2.45	7.86*	1.16*	3.62	15.27*
Tangible fixed assets	27.14*	28.09	0.25	18.85*	23.55	1.78*	22.50*	23.61	0.35
Financial fixed assets	2.33*	4.26	5.93*	3.51*	4.91	2.84*	7.90*	12.10	3.80*
Stocks	21.16*	19.07	-0.71*	18.65*	17.84	-0.31	19.88*	15.07	-1.73*
Trade debtors	28.15*	35.56	1.88*	31.25*	34.69	0.79	36.32*	31.79	-0.89*
Other debtors	3.86*	7.10	6.01*	4.01*	6.58	4.57*	6.05*	10.29	5.00*
Current Investment	0.54*	1.38	11.07*	1.70*	1.43	-1.14	3.17*	1.89	-2.88*
Cash at bank and in hand	4.24*	5.20	1.62*	4.51*	4.64	0.21	2.98*	3.33	0.85
Prepayments and accrued income	0.97*	1.16	1.45	1.14*	0.98	-0.99	2.02*	0.55	-5.21*
Total assets	90.20	104.5	1.13	84.84	97.11	1.03	101.9	102.2	0.02

Fitted values and trends presented in this table are based on equation 2.1. A (*) in the "1982" columns denotes that the estimated constant term $(\widehat{\alpha}_{c,d})$ is significant at the 5% confidence level. A (*) in the "growth" columns denotes that the estimated trend parameter $\left(\widehat{\beta}_{c,d}\right)$ is significant at the 5% confidence level. Beginning of period and end of period values for "Total assets" are computed as the sum of the estimated values of each of the items available.

[a] Average annual growth rate as defined at the beginning of subsection 2.3.2.

Table 2.9: Fitted Values and Trends of the Balance Sheet Ratios: Italy.
(values expressed in percentage points of Net Turnover)

	Liabilities								
	Small			*Medium*			*Large*		
	1982	1996	growth[a]	1982	1996	growth[a]	1982	1996	growth[a]
Amounts owed to credit institutions	13.85*	21.07	3.72*	14.45*	18.38	1.94*	15.01*	14.89	-0.06
Payments received on account of orders	0.97*	1.21	1.76	0.48	0.53	0.78	1.70*	1.51	-0.79
Trade creditors	22.01*	24.36	0.76*	19.68*	24.37	1.71*	21.30*	22.88	0.53
Other financial creditors	0.69	1.55	8.98*	0.73	3.80	30.22*	3.19*	5.87	6.02*
Other non-financial creditors	6.67*	6.71	0.04	6.04*	5.69	-0.42	5.23*	6.69	2.01*
Debenture loans	1.89*	0.93	-3.61*	1.54*	1.18	-1.70*	0.75*	0.69	-0.59
Amounts owed to credit institutions	5.70*	6.67	1.21	5.97*	6.49	0.62	11.99*	7.11	-2.91*
Trade creditors	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Other financial creditors	3.10*	3.07	-0.06	2.93*	2.38	-1.35	2.59*	2.80	0.59
Other non-financial creditors	0.11	1.06	64.06*	0.30*	0.79	11.63*	0.27*	0.47	5.22*
Provisions for liabilities and charges	4.21*	6.81	4.40*	5.36*	6.21	1.13	8.67*	8.17	-0.41
Accruals and deferred income	2.46*	1.14	-3.84*	2.66*	0.96	-4.57*	3.33*	0.63	-5.78*
Subscribed capital[b]	16.44*	14.06	-1.03	11.74*	12.61	0.53	17.86*	20.21	0.94
Revaluation reserve	5.15*	1.11	-5.60*	4.58*	1.00	-5.58*	3.69*	1.38	-4.46*
Reserves	6.35*	12.17	6.55*	5.86*	11.00	6.26*	4.77*	9.52	7.11*
Profits or losses[c]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total liabilities	89.60	101.9	0.98	82.33	95.38	1.13	100.3	102.8	0.18

Fitted values and trends presented in this table are based on equation 2.1. A (*) in the "1982" columns denotes that the estimated constant term $(\widehat{\alpha}_{c,d})$ is significant at the 5% confidence level. A (*) in the "growth" columns denotes that the estimated trend parameter $\left(\widehat{\beta}_{c,d}\right)$ is significant at the 5% confidence level. Beginning of period and end of period values for "Total liabilities" are computed as the sum of the estimated values of each of the items available.

[a] Average annual growth rate as defined at the beginning of subsection 2.3.2.

[b] Subscribed capital and share premium account.

[c] Profit or losses for the financial year and brought forward.

Table 2.10: Fitted Values and Trends of the Balance Sheet Ratios: Spain.
(values expressed in percentage points of Net Turnover)

	Assets								
	Small			*Medium*			*Large*		
	1982	1996	growth[(a)]	1982	1996	growth[(a)]	1982	1996	growth[(a)]
Subscribed capital unpaid	0.13*	0.15	0.58	0.12*	0.10	-1.19	0.00	0.00	-3.99
Intangible fixed assets	1.41*	1.51	0.50	1.29*	1.86	3.09	2.95*	1.66	-3.14*
Tangible fixed assets	30.21*	24.69	-1.30	30.49*	28.56	-0.45	43.33*	31.58	-1.94*
Financial fixed assets	1.71*	2.51	3.36	3.38*	5.22	3.89*	7.14*	11.37	4.24*
Stocks	19.80*	15.25	-1.64*	22.17*	15.21	-2.24*	24.44*	12.92	-3.37*
Trade debtors	31.94*	27.92	-0.90	35.87*	30.60	-1.05*	34.65*	27.27	-1.52*
Other debtors	1.90*	1.88	-0.08	2.97*	2.79	-0.43	3.41*	6.18	5.80*
Current Investment	0.74*	3.13	22.94*	1.33*	3.68	12.54*	1.84*	2.83	3.88*
Cash at bank and in hand	5.05*	5.52	0.66	4.00*	3.31	-1.24*	2.91*	1.39	-3.73*
Prepayments and accrued income	0.61*	0.17	-5.12*	0.82*	0.16	-5.74*	1.04*	0.14	-6.20*
Total assets	93.51	82.74	-0.82	102.4	91.49	-0.76	121.7	95.35	-1.55

Fitted values and trends presented in this table are based on equation 2.1. A (*) in the "1982" columns denotes that the estimated constant term $(\widehat{\alpha}_{c,d})$ is significant at the 5% confidence level. A (*) in the "growth" columns denotes that the estimated trend parameter $\left(\widehat{\beta}_{c,d}\right)$ is significant at the 5% confidence level. Beginning of period and end of period values for "Total assets" are computed as the sum of the estimated values of each of the items available.

[(a)] Average annual growth rate as defined at the beginning of subsection 2.3.2.

Table 2.11: Fitted Values and Trends of the Balance Sheet Ratios: Spain.
(values expressed in percentage points of Net Turnover)

	Liabilities								
	Small			*Medium*			*Large*		
	1982	1996	growth[a]	1982	1996	growth[a]	1982	1996	growth[a]
Amounts owed to credit institutions	18.62*	11.87	-2.59*	23.10*	14.13	-2.77*	25.45*	8.02	-4.89*
Payments received on account of orders	0.03	0.09	13.73	-0.13	1.17	n.d.*	-0.46*	2.20	n.d.*
Trade creditors	18.33*	18.28	-0.02	18.13*	18.25	0.05	16.91*	17.71	0.34
Other financial creditors	0.56*	1.38	10.39*	0.44	2.35	30.95*	0.15	4.58	207.2*
Other non-financial creditors	7.65*	6.42	-1.15	8.42*	6.13	-1.95*	9.54*	7.65	-1.41*
Debenture loans	0.01	0.04	20.72	0.10	0.01	-6.14	0.69*	0.17	-5.40*
Amounts owed to credit institutions	5.37*	6.40	1.36	6.82*	4.81	-2.10	12.36*	5.03	-4.23*
Trade creditors	-0.06*	0.24	n.d.*	-0.03	0.17	n.d.*	-0.01	0.12	n.d.*
Other financial creditors	4.32*	2.06	-3.74*	3.68*	1.53	-4.18*	5.46*	4.21	-1.63
Other non-financial creditors	-0.05*	0.73	n.d.*	-0.06*	0.79	n.d.*	0.01	0.22	164.3*
Provisions for liabilities and charges	0.31	0.36	1.11	0.43	1.23	13.29	0.06	7.24	841.1*
Accruals and deferred income	1.43*	-0.05	-7.39*	2.40*	-0.07	-7.36*	2.77*	0.05	-7.01*
Subscribed capital[a]	20.44*	11.59	-3.09*	18.51*	17.09	-0.55	22.04*	27.00	1.61*
Revaluation reserve	8.61*	-0.90	-7.89*	11.67*	-1.75	-8.21*	12.35*	-0.93	-7.68*
Reserves	12.00*	23.58	6.90*	13.88*	23.63	5.02*	12.47*	16.56	2.34*
Profits or losses[a]	-3.92*	2.27	n.d.*	-4.84*	0.31	n.d.*	-5.34*	-2.08	n.d.
Total liabilities	93.65	84.35	-0.71	102.5	89.79	-0.89	114.4	97.77	-1.04

Fitted values and trends presented in this table are based on equation 2.1. A (*) in the "1982" columns denotes that the estimated constant term $(\widehat{\alpha}_{c,d})$ is significant at the 5% confidence level. A (*) in the "growth" columns denotes that the estimated trend parameter $\left(\widehat{\beta}_{c,d}\right)$ is significant at the 5% confidence level. Beginning of period and end of period values for "Total liabilities" are computed as the sum of the estimated values of each of the items available.
[a] Average annual growth rate as defined at the beginning of subsection 2.3.2. *n.d.* stands for "not defined". When estimated constant is negative is not possible to apply our definition of average growth rate. The underlying estimate of the trend parameter may be in any case significant.
[a] Subscribed capital and share premium account.
[a] Profit or losses for the financial year and brought forward.

2.4 Balance Sheet Dynamics at the Business Cycle Frequencies

The goal of this section is to complement the evidence in favor of a certain degree of heterogeneity in the structural components of the balance sheet of different classes of firms with a similar information related to the business cycle components. This analysis is intended to provide a first piece of evidence about heterogeneity in the way firms of different type react to business cycle impulses by temporarily change their balance sheet structure.

2.4.1 Estimation Methodology

To obtain information about the relative importance of the different items of the balance sheet in explaining changes in the balance sheet structure we have exploited the possibility provided by BACH to track groups composed by the same firms for two consecutive years[17] and we have constructed for each possible item of the asset and of the liability sides "i", for each country "c", for each sub-sector "s" and for each point in time "t" the following indicator:

$$V^i_{c,s,d,t} = \frac{\frac{\Delta X^i_{c,s,d,t}}{n_{c,s,d,t}} \cdot T}{\sum_t \sum_i \frac{\left|\Delta X^i_{c,s,d,t}\right|}{n_{c,s,d,t}}} \tag{2.2}$$

where $X^i_{c,s,d,t}$ is the sum of the book values of item "i" for the firms that belong to class dimension "d", sector "s" and country "c", deflated with the GDP deflator. $\Delta X^i_{c,s,d,t} = X^i_{c,s,d,t} - X^i_{c,s,d,t-1}$. $n_{c,s,d,t}$ is the number of firms in the group at time "t".[18] The index in (2.2), that is similar in the spirit to those usually adopted in to evaluate the degree of openness of an economy to international trade, may therefore be interpreted as the percentage of the sum of absolute variations (computed across items and across time) explained by a single item of the balance sheet in a given. The larger this indicator is, the larger is the contribution of a specific item in explaining variations in the composition of the balance sheet. The next step has been to estimate

[17] At each point in time, and for a firm-class characterized by a size, a sector and a country, BACH provides two data points (for each item of the balance sheet). One is constructed in such a way to include in the sample the same firms that were available in the previous year, the other with all the firms of the group, that is adding "new entries" to "incumbent" and removing those that will drop out the next year in such a way to have directly comparable data for two consecutive years.

[18] Note that, for the reasons explained above, $n_{c,s,d,t} = n_{c,s,d,t-1}$.

the following equation for each item of the balance sheet and each country under analysis.[19]

$$
\begin{aligned}
V^i_{c,s,d,t} &= \alpha_{c,sm} + \alpha_{c,me} + \alpha_{c,la} + \beta_{c,sm}t_{c,sm} + \beta_{c,me}t_{c,me} + \beta_{c,la}t_{c,la} + \\
&+ \gamma_{c,sm,1}Y_{c,sm,t} + \gamma_{c,sm,2}Y_{c,sm,t-1} + \gamma_{c,me,1}Y_{c,me,t} + \\
&+ \gamma_{c,me,2}Y_{c,me,t-1} + \gamma_{c,la,1}Y_{c,la,t} + \gamma_{c,la,2}Y_{c,la,t-1} + \epsilon_{c,s,d,t} \qquad (2.3)
\end{aligned}
$$

where $V^i_{c,s,d,t}$ is the index described above, $\alpha_{c,i}$ are dimension specific dummies that are equal to one if $i = d$ (with *d*imension either *sm*all, *me*dium or *la*rge) and zero otherwise, t_i is a time trend dummy that assumes trend values if i=d and zero otherwise and, finally, $Y_{i,t}$ is a cyclical dummy that assumes the value of the industrial production growth rate if $i = d$ and zero otherwise. The trend terms have been included to be sure to disentangle cyclical from trend component in the dynamic evolution of the volatility indicator.[20] Once the parameters have been estimated we have fitted the cyclical component for each possible item (i), country (c) and size class (d):

$$
C\hat{Y}C^i_{c,d,t} = \hat{\gamma}_{c,d,1}Y_{c,d,t} + \hat{\gamma}_{c,d,2}Y_{c,d,t-1} \qquad (2.4)
$$

and we have computed the variance of each of the estimated series. The results (variances are multiplied by 100) are presented in the tables 2.12 to 2.15. We report both estimated variances and the relative (with respect to the sum of all the variances in the asset or liability side of the balance sheet) importance of each item. This last indicator is important because it is not possible to compare estimated variances across countries since they depend also on the volatility of contemporaneous and lagged industrial production indexes.

2.4.2 Main Results

France

With respect to the asset side of the balance sheet the results for French firms suggest that there are not substantial differences in the way firms of different dimensions react to business cycle evolutions. In all the three cases the volatility of the trade debtors accounts for more than fifty percent of

[19]The equation is estimated with this specification to allow for, within country, within year, within size, correlation in error terms.

[20]A trend component could in principle emerge if the GDP deflator is not able to capture completely the effect of the increase in the nominal value of the different items of the balance sheet.

total volatility. In addition in all the size - classes variations in stocks and tangible fixed assets account for most of the remaining volatility.

As far as the liability side is regarded the items of small and medium French firms show similar sensitivities to business cycle conditions. In particular in both classes of firms the variations in the amount of debts due to trade partners turns out to be the most important source of volatility followed by the changes in profits and by the changes in the level of financing obtained through banks. On the other side changes in the liability structure of large French manufacturing firms are almost equivalently caused by variations in profits and by fluctuations in the amounts of debts due to trade partners. The volatility in debts with credit institutions and with other types of financial creditors seem plays a significant but minor role.

Germany

While the items in the asset side of small German firms show cyclical volatilities that are similar to those of their French counterpart, medium and large firms seem to react to business cycle conditions mostly through variations in stocks and tangible fixed assets. Differently from what we have seen for France, in medium and, especially, large German firms trade credit seems to play only a marginal role.

The analysis of the cyclical dynamics of the liability side of German firms highlights the existence of a large number of contributors to its total volatility. In particular it emerges that in each of the size class, short term debt with banks, debts with trade partners, reserves and profits play a significant role in shaping cyclical changes in the balance sheet. However it also turns out that the relative weight of short term liabilities is larger for smaller firms while that of capital and reserves is more important for larger firms.

Italy

Italian medium and large firms show characteristics very similar to their French counterparts with trade credit being by far the most volatile item (followed by stocks and tangible fixed assets). The only difference seems to be the fact that in Italian large firms also financial fixed assets show some dynamic at a business cycle frequency. On the other side stocks, tangible fixed assets and trade play an almost equivalent role in shaping the business cycle dynamics of the asset side of small Italian firms.

As far as the liability side is regarded, items of small and medium Italian firms show sensitivities to business cycle conditions that are similar to each other and to their French counterparts: the variations in the amount of debt with trade partners is the most important source of volatility followed by changes in profits. On the other side changes in the liability structure of large Italian manufacturing firms are almost totally and equivalently caused by variations in profits and by fluctuations in the amount of debts with trade partners.

Spain

Spanish firms show the largest degree of heterogeneity across size classes. The items of the asset side of small Spanish firms are characterized by sensitivities to business cycle dynamics that are similar to those of French and German small firms. Trade credit is by far the first source of volatility, stocks and tangible fixed assets plays some significant, but less relevant, role. Medium sized Spanish firms behave similarly to Italian small firms and, to a lesser extent, to German medium firms in the fact that the volatility of the asset side of the balance sheet is, approximately, equally caused by the volatility of tangible fixed assets, stocks and trade credit. Differently from all the typologies of firms analyzed in these work the volatility of the balance sheet of large Spanish firms is mainly due to changes in the amount of tangible fixed assets and variations in the amount of stocks.

The analysis of the cyclical dynamics in the liability side of Spanish firms reveals the existence of two main sources of volatility, namely changes in commercial debts and in profits. However, while the first source affects predominantly small and medium firms, the latter is by far the most important source of change for large firms.

The general impression that one can get from these results is the fact that, even if it has been possible to individuate some general common patterns across firms belonging to different countries and different size classes, there exist a large number of heterogeneities in the way distinct firms react to the business cycle. In particular even if in most of the cases the items of the balance sheet that have shown significant business cycle dynamics are those that are well known to be strongly cyclical, like commercial credit, commercial debt, stocks and profits, it has also been possible to find out that the size of the firms is not irrelevant in shaping the way in which the different items of the balance sheet react to business cycle impulses. We conclude this section by noticing that a piece of evidence that should be more deeply analyzed by future research is related to the large importance of trade credit and trade debt in explaining cyclical volatility of most of the corporate structures. Our impression is that it would be extremely important to verify whether this cyclicality is purely mirroring the fact that also sales and stocks (related respectively to trade credit and trade debt) show a cyclical behavior or if they play some other independent role.

Table 2.12: Cyclical Component: Absolute and Relative Importance. France.

	Assets					
Firms' size	Small		Medium		Large	
	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.
Subscribed capital unpaid	0.000	0.000	0.000*	0.000	0.000	0.000
Intangible fixed assets	0.000	0.000	0.000	0.000	0.000	0.000
Tangible fixed assets	0.604*	0.103	0.415*	0.065	0.352*	0.104
Financial fixed assets	0.009	0.002	0.008	0.001	0.092	0.027
Stocks	0.986*	0.169	1.997*	0.310	0.718*	0.213
Trade debtors	4.019*	0.687	3.846*	0.597	2.106*	0.624
Other debtors	0.188*	0.032	0.100*	0.016	0.028	0.008
Current Investment	0.013	0.002	0.056*	0.009	0.024	0.007
Cash at bank and in hand	0.029*	0.005	0.016*	0.002	0.054*	0.016
Prepayments and accrued income	0.001*	0.000	0.002*	0.000	0.001*	0.000
	Liabilities					
Firms' size	Small		Medium		Large	
	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.
Amounts owed to credit institutions	0.155*	0.050	0.301*	0.079	0.127*	0.067
Payments received on account of orders	0.002	0.001	0.001	0.000	0.000	0.000
Trade creditors	1.947*	0.627	2.512*	0.661	0.668*	0.351
Other financial creditors	0.000	0.000	0.001	0.000	0.012*	0.006
Other non-financial creditors	0.033*	0.011	0.021*	0.006	0.011	0.006
Debenture loans	0.000*	0.000	0.000	0.000	0.002	0.001
Amounts owed to credit institutions	0.320*	0.103	0.131*	0.034	0.059*	0.031
Trade creditors	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Other financial creditors	0.005	0.001	0.013	0.003	0.192*	0.101
Other non-financial creditors	0.006*	0.002	0.011*	0.003	0.010*	0.005
Provisions for liabilities and charges	0.002	0.001	0.003	0.001	0.002	0.001
Accruals and deferred income	0.000	0.000	0.000	0.000	0.000	0.000
Subscribed capital$^{(a)}$	0.000	0.000	0.004	0.001	0.042	0.022
Revaluation reserve	0.000	0.000	0.000*	0.000	0.000	0.000
Reserves	0.080*	0.026	0.043*	0.011	0.035*	0.019
Profits or losses$^{(b)}$	0.557*	0.179	0.756*	0.199	0.744*	0.391

(*) denotes that the underlying estimated cyclical parameters are jointly significant at a 5% level. All the figures presented in this table are rounded. $^{(a)}$ Subscribed capital and share premium account. $^{(b)}$ Profit or losses for the financial year and brought forward.

Table 2.13: Cyclical Component: Absolute and Relative Importance. Germany.

	Assets					
Firms' size	Small		Medium		Large	
	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.
Subscribed capital unpaid	0.000	0.000	0.000	0.000	0.000	0.000
Intangible fixed assets	0.000	0.000	0.002	0.000	0.002*	0.001
Tangible fixed assets	0.271	0.198	0.920*	0.198	0.909*	0.277
Financial fixed assets	0.011	0.008	0.035	0.008	0.004	0.001
Stocks	0.109	0.079	2.707*	0.583	1.782*	0.542
Trade debtors	0.729*	0.532	0.842*	0.181	0.245*	0.075
Other debtors	0.146*	0.107	0.125	0.027	0.207	0.063
Current Investment	0.002	0.001	0.003*	0.001	0.042*	0.013
Cash at bank and in hand	0.101*	0.074	0.004	0.001	0.096	0.029
Prepayments and accrued income	0.000	0.000	0.001*	0.000	0.000*	0.000
	Liabilities					
Firms' size	Small		Medium		Large	
	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.
Amounts owed to credit institutions	0.513*	0.232	0.738*	0.264	0.170	0.130
Payments received on account of orders	0.008	0.004	0.003	0.001	0.000	0.000
Trade creditors	0.696*	0.315	0.713*	0.255	0.180*	0.138
Other financial creditors	0.033	0.015	0.038	0.014	0.242	0.185
Other non-financial creditors	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Debenture loans	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Amounts owed to credit institutions	0.061	0.028	0.023	0.008	0.015	0.012
Trade creditors	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Other financial creditors	0.078*	0.035	0.057*	0.020	0.026	0.019
Other non-financial creditors	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Provisions for liabilities and charges	0.191*	0.086	0.100*	0.036	0.010	0.008
Accruals and deferred income	0.000	0.000	0.000	0.000	0.000	0.000
Subscribed capital[(a)]	0.007	0.003	0.047	0.017	0.017	0.013
Revaluation reserve	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Reserves	0.191*	0.086	0.556*	0.198	0.307*	0.235
Profits or losses[(b)]	0.434*	0.196	0.526*	0.188	0.341*	0.261

(*) denotes that the underlying estimated cyclical parameters are jointly significant at a 5% level. All the figures presented in this table are rounded. [(a)] Subscribed capital and share premium account. [(b)] Profit or losses for the financial year and brought forward.

Table 2.14: Cyclical Component: Absolute and Relative Importance. Italy.

	Assets					
Firms' size	Small		Medium		Large	
	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.
Subscribed capital unpaid	0.000	0.000	0.000	0.000	0.000	0.000
Intangible fixed assets	0.001	0.001	0.004*	0.002	0.002	0.002
Tangible fixed assets	0.255*	0.301	0.108*	0.054	0.102*	0.078
Financial fixed assets	0.005	0.006	0.000	0.000	0.163*	0.125
Stocks	0.309*	0.365	0.533*	0.268	0.227*	0.174
Trade debtors	0.250	0.295	1.252*	0.629	0.745*	0.571
Other debtors	0.001	0.002	0.053*	0.027	0.030	0.023
Current Investment	0.012*	0.014	0.015*	0.008	0.015	0.012
Cash at bank and in hand	0.010	0.011	0.017*	0.008	0.017*	0.013
Prepayments and accrued income	0.004*	0.005	0.007*	0.003	0.003*	0.002
	Liabilities					
Firms' size	Small		Medium		Large	
	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.
Amounts owed to credit institutions	0.026	0.025	0.101*	0.060	0.038	0.038
Payments received on account of orders	0.000	0.000	0.001	0.001	0.000	0.000
Trade creditors	0.680*	0.649	1.221*	0.719	0.380*	0.382
Other financial creditors	0.010*	0.010	0.001	0.001	0.035	0.035
Other non-financial creditors	0.003	0.002	0.005	0.003	0.019*	0.019
Debenture loans	0.002*	0.002	0.004*	0.002	0.000	0.000
Amounts owed to credit institutions	0.001	0.001	0.010	0.006	0.012	0.012
Trade creditors	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Other financial creditors	0.004	0.004	0.003	0.002	0.024*	0.024
Other non-financial creditors	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Provisions for liabilities and charges	0.010*	0.010	0.003*	0.002	0.002	0.002
Accruals and deferred income	0.002*	0.002	0.004*	0.003	0.015*	0.015
Subscribed capital[(a)]	0.012	0.011	0.006	0.003	0.002	0.002
Revaluation reserve	0.002*	0.001	0.003*	0.002	0.003*	0.003
Reserves	0.048*	0.046	0.092*	0.054	0.059*	0.060
Profits or losses[(b)]	0.249*	0.237	0.244*	0.144	0.405*	0.408

(*) denotes that the underlying estimated cyclical parameters are jointly significant at a 5% level. All the figures presented in this table are rounded. [(a)] Subscribed capital and share premium account. [(b)] Profit or losses for the financial year and brought forward.

Table 2.15: Cyclical Component: Absolute and Relative Importance. Spain.

	Assets					
Firms' size	Small		Medium		Large	
	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.
Subscribed capital unpaid	0.000	0.000	0.000	0.000	0.000	0.000
Intangible fixed assets	0.016*	0.012	0.003	0.002	0.021*	0.018
Tangible fixed assets	0.150*	0.108	0.523*	0.296	0.692*	0.579
Financial fixed assets	0.002	0.001	0.011	0.006	0.070	0.059
Stocks	0.441*	0.317	0.737*	0.417	0.266*	0.223
Trade debtors	0.730*	0.525	0.477*	0.270	0.048	0.040
Other debtors	0.000	0.000	0.008	0.005	0.025	0.021
Current Investment	0.016	0.011	0.003	0.002	0.068*	0.057
Cash at bank and in hand	0.035*	0.025	0.005	0.003	0.004	0.003
Prepayments and accrued income	0.001*	0.001	0.001*	0.001	0.000	0.000
	Liabilities					
Firms' size	Small		Medium		Large	
	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.
Amounts owed to credit institutions	0.005	0.003	0.087*	0.056	0.045	0.022
Payments received on account of orders	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Trade creditors	0.465*	0.323	0.296*	0.189	0.079*	0.039
Other financial creditors	0.002	0.001	0.006	0.004	0.047	0.023
Other non-financial creditors	0.006	0.004	0.002	0.001	0.001	0.000
Debenture loans	0.000	0.000	0.000	0.000	0.000	0.000
Amounts owed to credit institutions	0.003	0.002	0.002	0.002	0.044*	0.022
Trade creditors	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Other financial creditors	0.004	0.002	0.007	0.004	0.057*	0.028
Other non-financial creditors	0.001	0.000	0.000	0.000	0.000	0.000
Provisions for liabilities and charges	0.000	0.000	0.001	0.000	0.014*	0.007
Accruals and deferred income	0.001*	0.000	0.001	0.000	0.000	0.000
Subscribed capital[a]	0.032*	0.022	0.039*	0.025	0.004	0.002
Revaluation reserve	0.029*	0.020	0.058*	0.037	0.058*	0.029
Reserves	0.047*	0.033	0.053*	0.034	0.135*	0.067
Profits or losses[b]	0.847*	0.588	1.013*	0.647	1.528*	0.760

(*) denotes that the underlying estimated cyclical parameters are jointly significant at a 5% level. All the figures presented in this table are rounded. [a] Subscribed capital and share premium account. [b] Profit or losses for the financial year and brought forward.

2.5 Conclusions

The analysis has provided a set of stylized facts about levels, trends and business cycle dynamics of the balance sheet structures of firms characterized by different dimension and different nationalities. Even if it has been possible to find evidence in favor of some common patterns across different group of firms and if in many cases the items of the balance sheet that have shown to be the most responsive to the business cycle are the ones that are well known to be strongly cyclical, a sizable number of heterogeneities among firms belonging to different size classes and countries has emerged. This evidence suggests that the commonly adopted approach to assume homogeneity in firms' reaction to business cycle dynamics could in principle produce unreliable results. It is also important to stress that the heterogeneity that has emerged in these pages is based on two specific dimensions of diversity, namely the size of the firm and its country of origin and that, due to data availability, it has not been possible to investigate other important possible sources of heterogeneity like, just to make an example, the manufacturing sector to which the firm belongs. In the next chapter we construct on the evidence produced in this chapter by exploiting a unique panel, that includes about 2,000 Italian manufacturing firms and 14 years of data on individual prices and individual interest rates paid on several types of debt. In particular we address the existence of a channel of transmission of monetary policy, operating through the effect of interest expenses on the marginal cost of production, that is based on the amount of stocks and commercial credit and debt held by each firm.

Chapter 3

The Cost-Channel of Monetary Policy*

3.1 Introduction

A growing literature has addressed the possibility that monetary policy actions do not only affect aggregate demand, but also exert an influence on economic variables through the supply side; namely, they influence firms interest expenses on working capital and, as a consequence, marginal costs of production and output prices. The implications of such a conjecture are far reaching. The most apparent is that in the short run an increase in interest rates may cause prices to rise, rather than to fall. The possibility that monetary policy shares some of the features of a supply shock would also contribute to explain the large and persistent effects of monetary policy on the real economy. Last but not least, the existence of this effect may also have important consequences in the design of optimal policies, as it is likely to imply a worsening in the short-run output-inflation trade-off and to call for a more gradual stabilization of inflationary shocks.

However, empirical evidence in favor of this hypothesis is not abundant and still controversial. Virtually all of it is based on aggregate - sometimes sectoral - data and, in particular, on the identification of a short term positive response of aggregate prices to interest rate shocks. It is well known that macro-evidence on the effects of monetary shocks is subject to substantial identification and specification problems and, consequently, to considerable uncertainty of interpretation. The issue, therefore, is still not settled.

This papers contribution is to exploit the rich information from a unique micro-dataset of Italian manufacturing firms, covering 14 years and about

*This is a joint research with E.Gaiotti (Bank of Italy).

2000 firms, which, most notably, includes firm specific data on changes in output prices and on the interest rate paid on debt. The availability of disaggregated information helps us to make important advances vis--vis the existing empirical literature, avoiding the identification problems typical of time-series estimates. By exploiting cross section variability in output prices and interest expenses we are able to disentangle firm-specific cost-channel effects from demand effects, which are aggregate in nature. Moreover, the availability of firm level information on variables that should be relevant for a cost-channel to exist enables us to construct supplementary and sharper tests for the existence of the cost-channel.

Our analysis, based on firm-level data, identifies a significant effect of interest expenses on firms prices. The established hypothesis that this effect is linked to the role of working capital in the production process of the firm, i. e. to a temporal mismatch between factor payments and sales receipts (Hicks (1979), Christiano, Eichenbaum and Evans (1997) and Barth and Ramey (2002)) cannot be rejected. On the basis of the properties of standard theoretical macro-models which feature a cost-channel, we judge the size of this supply-side effect to be large enough to warrant careful consideration in the design of monetary policy.

The paper is organized as follows. Section 3.2 reviews the literature on the supply effects of monetary policy and sets out the specific contribution of this paper. Section 3.3 derives a price equation in which the interest rate is allowed to affect the marginal cost of producing output. This equation forms the basic specification to be used in the estimation stage. Section 3.4 presents the main features of our dataset. The main empirical results and some extensions are reported in sections 3.5 and 3.6. Section 3.7 concludes.

3.2 The Effects of Monetary Policy on Production Costs

3.2.1 Implications of the Existence of a Cost-Channel

The idea that interest expenses should be treated as a cost of production is long standing. The argument that a decrease in interest rates determines a reduction in prices via lower costs of production was already advanced in 1844 by Thomas Tooke, leading scholar of the banking school.[1] Hicks (1979) argues that the short-term interest rate should be considered as the price of

[1] See the survey by Ginzburg and Simonazzi (1997).

a particular factor of production (in addition to capital and labor), which he labels waiting time or inter-temporal switch in output. Seelig (1974) reports a famous version of the view that the interest rate affects costs of production, expressed by US congressman Wright Patman, chairman of the Joint Economic Committee, who in March 1970 argued that raising interest rates to fight inflation was like throwing gasoline on fire. Goodhart (1986) recounts the opinion of British businessmen, who still tend to regard interest rates as a cost and look to establish a price rise in response to increased interest rates. More recently, Evans (2002) quotes anecdotal information collected by Federal Reserve staff in times of rising interest rates, about the passing over of increasing inventory costs to prices. Similar arguments were also prominent in the debate on monetary policy and inflation in Italy in the 1970s. Andreatta (1973), quoting Grant (1972), advances the argument that a credit restriction can contribute to inflation when it bears on the supply side, limiting the financing of working capital. Valli (1979) argues that an increase in interest rates introduces inflationary pressures in the economy by increasing the firms cost of capital.

Barth and Ramey (2002) revive the argument that monetary policy may operate in the short run through a cost-channel (while in the longer run the demand channel dominates, consistently with money neutrality). They argue that monetary policy shocks affect the short-run productive capacity of the economy by shifting both the demand and supply functions in the same direction, and that this mechanism may contribute to explain three empirical regularities not well accounted for by standard theories: the degree of amplification and persistence of the real effects of monetary shocks, the empirical finding that the price level rises in the short-run in response to a monetary tightening (price puzzle) and the fact that, in the short run, the responses of the main macroeconomic variables to a monetary shock are more similar to those due to a technology shock than to a demand shock.[2] According to Barth and Ramey, the cost-channel is based on an active role of net working capital (inventories, plus trade receivables, less trade payables) in the production process and on the fact that variations in interest rate and credit conditions alter firms' short- run ability to produce final output by investing in net working capital. This effect may be modeled by directly assuming that inventories or working capital enter the production function (Ramey (1989) and Ramey (1992)) with the interest rate being the price of such a factor. Alternatively, a temporal mismatch between factor payments

[2]They present evidence showing that productivity and real wages fall after an adverse productivity shock or a restrictive monetary shock; in contrast, they rise after a negative demand shock.

and sales receipts may be explicitly modeled: Christiano et al. (1997) show that, in a model where output is produced only through labor and where the purchase of production factors must be financed through borrowing, the marginal cost of labor is equal to the wage times the gross nominal interest rate.[3] Interest rates affect production costs also in the models by Farmer (1984) and Christiano and Eichenbaum (1992). Another strand of literature links the existence of a credit channel of monetary transmission to supply-side effects of monetary policy, arguing that, due to the latter, tighter monetary policy may be inflationary (Stiglitz and Greenwald (2003)).[4]

The existence of a cost-channel can alter the optimal course of monetary policy in the face of various shocks, possibly in a substantial way. Ravenna and Walsh (2003) derive a cost-channel effect in a new-Keynesian framework based on optimizing behavior, again assuming that wages are paid in advance. They show that, under this assumption, an inflation-output trade-off arises even after productivity or demand disturbances and conclude claiming that optimal policy calls for more gradualism in the stabilization of the inflation rate. Under the assumption that all variable costs of production are paid one quarter in advance, the optimal policy response to an adverse shock on prices needs to be much more gradual. It can be shown that in their model, in case of a cost-push shock, it may even be an interest rate easing, as the central bank can in part offset the adverse cost-push shock by decreasing rates, thus relieving firms from interest expenses on their working capital.[5] However, the actual relevance of this conclusion crucially depend on the quantitative magnitude of the effect of interest rates on marginal costs.

3.2.2 Existing Evidence

Even if the cost-channel is becoming a common building block in general equilibrium macro models, the empirical evidence on its existence and relevance is still limited and mainly based on the identification of a short-run positive effect of interest rate increases on aggregate, or sectoral, price levels. Seelig (1974), based on two and three-digit industry data and on the assumption of mark-up pricing above average unit costs, argued that in the

[3]A different strand of literature concentrates on the effect of tighter liquidity constraints on prices through markups, rather than through marginal costs (Chevalier and Scharfstein (1996) and Bottasso, Galeotti and Sembenelli (1997)). Barth and Ramey (2002) stress the similarities with the cost-channel hypothesis.

[4]Fiorentini and Tamborini (2001) also emphasize the potential connection between credit conditions and firms' production activity as the "missing ring" in the "credit channel" literature.

[5]The point is illustrated in Appendix 3.I.

1950s and the 1960s the impact of interest rate changes on prices was fairly negligible. More recently, Barth and Ramey (2002) provide evidence in favor of the existence of a cost-channel in the US over the last forty years, showing that after a restrictive monetary policy shock the price/wage ratio increases (and productivity decreases) in a vector auto-regression. The latter finding is stronger in those (two-digits) industries that feature larger interest expenditures as a share of sales. Ravenna and Walsh (2003) estimate a stylized general equilibrium model for the US and find that the cost-channel exerts a statistically and economically significant role in determining price and output dynamics: a one percent increase in (quarter-on-quarter) interest rates affect the marginal cost of production by about 1 point. However, in a similar setting Rabanal (2003) obtains a much smaller value of the cost-channel coefficient.

Yet, there are a few shortcomings that affect more or less directly the results presented so far in the literature. It has been repeatedly shown that the empirical finding of a positive correlation between interest rate and prices, known as the price puzzle, is not necessarily related to a structural relationship but could simply reflect central banks reaction function (Sims (1992)) and the omission of some relevant variable from the analytical framework (Christiano et al. (1997) and Balke and Emery (1994)); as a consequence, the main empirical building block of the cost-channel conjecture rests on shaky ground.[6] More generally, the need to disentangle the effects of interest rates on the supply-side from those on the demand-side and the need to take into account the effect of output and prices on interest rates via the reaction function poses complex identification problems, which may also affect the estimation of GE models, so that estimates based on aggregated data are likely to provide inconclusive evidence on the magnitude of the cost-channel effect. This seems to be confirmed by the conflicting evidence reported by various authors. Even if in principle one could construct empirical frameworks that would allow for cleaner tests on the existence of the cost-channel, in most of the cases these should be based on the use of variables that, at the aggregate level, are either not available or lack the degree of inter-temporal variability which is necessary to identify cost-channel effects. Working capital is one example of such variables.

The strategy we adopt to get rid of the shortcomings that plague time series estimates is based on the observation that the main difference between the demand channel and the cost-channel is that the former is intrinsically aggregate (or sectoral) while the latter, being based on the amount of working capital owned by each firm and on its specific interest rate, is an individid-

[6]See also Gilchrist (2002) and Evans (2002).

ual effect. This implies that a direct way to search for an effect of interest rate changes on firms' pricing policies is to inspect individual output price responses to interest rate changes once all aggregate effects (including traditional monetary policy transmission through demand) and variations in material and labor costs are controlled away through, respectively, appropriate dummies and firm level information on variations in input costs. This approach has so far been constrained by data limitations and in particular by lack of information on firm-level prices and interest rates. We exploit the possibilities offered by the availability of a unique firm-level dataset (discussed in detail in section 3.4) which includes firm-specific information on annual changes in the price of output, as well as on interest rates and on the importance of working capital. The availability of firm level data is particularly appealing for different reasons. First it allows testing for the existence of a positive relationship between individual changes in interest rates and individual changes in output prices which, once aggregate effect are controlled for, might be interpreted as a condition for the existence of the cost-channel. Second, taking advantage of firm level information on both interest rates and on the weight of working capital in the production process, we are able to test for the relevance of the determinants of the cost-channel discussed by Barth and Ramey (2002). Finally, further information available in our dataset, as the frequency of price revisions by individual firms, allows us to perform several robustness tests of our conclusions. Our strategy consists of two steps. First we derive a firm level price equation that allows for a direct effect of interest rates on prices. Then we estimate a set of alternative empirical specifications of this equation to test for the existence of the cost-channel.

3.3 A Price Equation with a Cost-Channel

We derive a standard price equation in the spirit of Bils and Chang (2000), assuming a production technology which uses labor, capital and material inputs. Output prices are set in a framework of monopolistic competition, as a mark-up over marginal costs, while the firm behaves as a price taker on the factor market. Material inputs are included to allow for the role of working capital: we impose that a fixed fraction of these inputs must be held as inventories and financed. We also assume that a fraction of labor inputs must be paid in advance and externally financed. Output is produced according to:[7]

[7]The price equation derived in this section does not require constant return to scale (the assumption of market power ensures that second order conditions are met anyway).

$$y_t = A_t M_t^{\delta} N_t^{\beta} k_t^{\alpha} \tag{3.1}$$

where A_t reflects technology, M_t is material input, K_t is capital, N_t is labor. A cost-channel is introduced by assuming that labor and material inputs must be paid in advance and have to be financed at an interest rate equal to r_t. More specifically, we assume that in each production period the firm must hold a fixed proportion k_M of material inputs as working capital (inventories less net commercial debt)[8] and pay a fixed proportion, k_N, of the wage bill before receiving the labor services. The latter assumption is included because it is widely used in the theoretical literature; however, it is not essential, as it can be dropped without affecting the overall results.[9] Denoting the prices of material inputs, labor and capital respectively as v, w and c, and the interest rate paid to finance working capital and anticipated wages as r_t, total cost are given by:

$$C_t = \nu_t M_t (1 + k_m r_t) + w_t N_t (1 + k_N r_t) + c_t K_t \tag{3.2}$$

Building on first order conditions of the cost minimization problem, and defining $\gamma \equiv \delta / (\delta + \alpha + \beta)$, the log-change in the marginal cost (a dot above a variable indicates log- variations) is equal to:[10]

$$\dot{MC}_t = (1-\gamma)\dot{w}_t + \gamma \dot{v}_t - \left[\dot{y}_t - \left(\gamma \dot{M}_t + (1-\gamma)\dot{N}_t\right)\right] + h\Delta r_t + (1-\gamma) k_N \Delta r_t \tag{3.3}$$

where we defined $h \equiv \gamma k_M$ and simplified out the user cost of capital c_t.[11] The price equation is then obtained by equating the change in price to the

We adopt a Cobb-Douglas specification for the sake of simplicity; similar results could be obtained with more general functional forms, as in Bils and Chang (2000), or even assuming that capital is a fixed factor in the short run, as in Christiano et al. (1997).

[8] The assumption of a fixed k_M is made for the sake of analytical simplicity. It could alternatively be assumed that inventories directly enter the production function, implying that their demand is inversely related to interest rates. It can be shown that this would not substantially alter the marginal cost equation 3.4 in a neighborhood of equilibrium.

[9] The assumption by Christiano et al. (1997) that labor costs are anticipated for the whole production period corresponds, in our notation, to $k_N = 1$.

[10] See Appendix 3.II for details on the derivation. The change in marginal cost can also be written as: $\dot{MC}_t = (1-\gamma)\dot{w}_t + \gamma \dot{v}_t + T\dot{F}P_t + \alpha (\alpha + \beta + \delta)^{-1} \left(\dot{N}_t - \dot{K}_t\right) + h\Delta r_t + (1-\gamma) k_N \Delta r_t$. This formulation, akin to the one used by Bils and Chang (2000), is written in terms of the change in total factor productivity (TFP) and a measure of the labor/capital ratio. For such a formulation to be empirically operational, an estimate of K is needed, whose derivation would go beyond the scope of this paper.

[11] Simplifying away c_t is convenient since direct measures of this variable are problematic and not central to the purpose of this paper. In equation (3.3), movements in the user cost of capital indirectly affect marginal cost by inducing movements in labor productivity.

change in marginal cost and change in mark-up.[12] The final price equation can be written in two equivalent ways:

$$\dot{P}_t = \dot{\mu}_t + (1-\gamma)\,\dot{w}_t + \gamma\dot{v}_t - \left[\dot{y}_t - \left(\gamma\dot{M}_t + (1-\gamma)\,\dot{N}_t\right)\right] + h\Delta r_t + (1-\gamma)\,k_N\Delta r_t \quad (3.4)$$

$$\dot{P}_t = \dot{\mu}_t + (1-\gamma)\,U\dot{L}C_t + \gamma U\dot{M}C_t - h\Delta r_t + (1-\gamma)\,k_N\Delta r_t \quad (3.5)$$

Equation (3.4) includes on the right-hand side the the change in the interest rate, which enters in two interaction terms: multiplied by working capital/total costs ratio(h) and multiplied by a term proportional to the value added/total costs ratio $(1-\gamma)$. Moreover, the equation also includes the change in input prices and wages, as well as, in square brackets, a measure of the change in productivity which is specified as a weighted average of the change in output per worker and the change in output per unit of input. The role of this term is threefold:[13] it captures the effect on prices of exogenous changes in productivity due to the term A_t, it measures the effect of movements in the user cost of capital c_t (which induce changes in the labor/capital and input/capital ratios) and, in case of non-constant returns to scale, it also captures scale effects. Equation (3.5) is expressed directly in terms of the change in unit costs (unit material input cost, $U\dot{M}C_t \equiv \dot{y}_t - \dot{\nu}_t - \dot{M}_t$, and unit labor costs, $U\dot{L}C_t \equiv \dot{y}_t - \dot{w}_t - \dot{N}_t$), multiplied by the relevant shares. From first order conditions, the parameter γ equals the share of material inputs costs over total costs: $\gamma = (\nu_t M_t\,(1+k_m r_t))/\,C_t$; consequently, the parameter h is approximately equal to the ratio between working capital and total costs C. Equations (3.4) and (3.5) are mapped in two empirical specifications. The first one is:

$$\begin{aligned}\dot{P}_{i,t} \;\;=\;\; & \dot{\mu}_{s,t} + a_1\left[(1-\gamma_i)\,\dot{w}_{s,t}\right] + a_2\left[\gamma_i\dot{v}_{s,t}\right] - a_3\left[\dot{y}_{i,t} - \left(\gamma_i\dot{M}_{i,t} + (1-\gamma_i)\,\dot{N}_{i,t}\right)\right] + \\ & + a_4\left[h_i\Delta r_{i,t}\right] + a_5\left[(1-\gamma_i)\,\Delta r_{i,t}\right] + a_6\left[CU_{i,t}\right] \quad (3.6)\end{aligned}$$

[12] The implicit assumption is that firms adjust their price each period, which is not completely unrealistic given the annual frequency of our data. The issue is addressed in more detail in section 3.5.

[13] The term in square brackets may be written as:

$$(\alpha+\beta+\delta)^{-1}\left[\dot{A}_t - \alpha\,(\dot{c}_t - \dot{w}_t) + (\alpha+\beta+\delta-1)\,\dot{y}_t\right].$$

where sub-indexes "s" and "i" denote that a variable is measured, respectively, at a sectoral or at an individual level. In equation (3.6), $\dot{P}_{i,t}$ is the change in output price for firm i in period t; $\dot{\mu}_{s,t}$ is the time-varying change in the mark-up, measured by the inclusion of time-sector dummies, which also captures all aggregate effects on prices; $(1-\gamma_i)\,\dot{w}_{s,t}$ is the change in contractual wages in branch s (to which the firm belongs), times the value added - total costs ratio for firm i; similarly, $\gamma_i \dot{v}_{s,t}$ is the change in input prices in branch s times the share of material input over total costs in firm i; $\left[\dot{y}_{i,t} - \left(\gamma_i \dot{M}_{i,t} + (1-\gamma_i)\,\dot{N}_{i,t}\right)\right]$ is a measure of productivity change; $h_i \Delta r_{i,t}$ is the change in firm-specific interest rate, times the firm-specific variable h_i, which is measured as the fraction of net working capital over total costs; $(1-\gamma_i)\,\Delta r_{i,t}$ interacts the change in the interest rate with the share of value added in total costs; this term is based on the assumption that the fraction of labor cost which have to be anticipated (k_N) is constant across firms. $CU_{i,t}$ is a measure of capacity utilization in firm i at time t. The latter term, which does not appear in in equation (3.4), is included to control for firm-specific changes in markups.[14] In our estimates, the results proved to be robust to the inclusion or exclusion of this variable. We expect the estimated parameters a_1 - a_4 to be equal to 1, as suggested by equation (3.4), and a_5 and a_6 to be positive. We are in particular interested in the sign and size of coefficients a_4 and a_5, which measure the cost-channel effect. The second specification is:

$$\begin{aligned}\dot{P}_{i,t} &= \dot{\mu}_{s,t} + b_1\left[(1-\gamma_i)\,U\dot{L}C_{i,t}\right] + b_2\left[\gamma_i U\dot{M}C_{i,t}\right] - b_3\left[h_i \Delta r_{i,t}\right] + \\ & \quad b_4\left[(1-\gamma_i)\,\Delta r_{i,t}\right] + b_5\left[CU_{i,t}\right] \qquad (3.7)\end{aligned}$$

where $(1-\gamma_i)\,U\dot{L}C_{i,t}$ is the change in firm is unit labor cost, times the share of value added over total cost in the same firm and $\gamma_i U\dot{M}C_{i,t}$ is the change in firm is unit material input cost times the share of material input cost over total cost. The other terms are the same as in equation (3.6). We expect coefficients b_1 - b_3 to be equal to one, as in equation (3.5), and b_4 and b_5 to be positive. Again, we are particularly interested in the sign and size of coefficients b_3 and b_4.

[14] Domowitz, Hubbard and Petersen (1988) point out that there is a strong positive relationship between capacity utilization and market power. Marchetti (2002) provides evidence in favor of this positive relationship for Italian manufacturing firms. The inclusion of capacity utilization in the estimated equations can also represent a short-run, transitory effect of idle capacity on the pricing behavior of the firm (Eckstein and Fromm (1968)).

3.4 The Data

The panel is obtained combining information from three datasets: the Survey of Investment in Manufacturing (SIM, Indagine sugli Investimenti delle Imprese Industriali), the Company Accounts Data Service (CADS, Centrale dei Bilanci) and the Italian Credit Register (CR, Centrale dei Rischi); the latter source is only used in some of the regressions.

The SIM database includes individual information on Italian manufacturing firms since 1978. Data are collected at the beginning of each year interviewing a stratified sample[15] of between 500 and 1000 firms with more than 50 employees. The first part of the survey includes qualitative and quantitative information on the corporate structure of the firm, employment, investment, current production and technical capacity. The second part covers specific topics that change year by year. An intense process of data revision is carried out by officials of the Bank of Italy. A particular effort has been spent in trying to keep information as much comparable as possible in subsequent years. Still, the dataset may be affected by some adverse self-selection bias since firms belonging to SIM are interviewed on a voluntary base. To our purpose, a major advantage of SIM is represented by the fact that it contains information on a number of variables that are usually not available. Very importantly, since 1988 it includes the average percentage change in output prices, which is one of the core variables in our analysis.

The CADS database contains detailed balance sheet and profit and loss information on Italian non-financial firms. Data are collected by a consortium, which includes the Bank of Italy and all major Italian commercial banks, interested in pooling information about their clients. Data are available in electronic format since 1982; the sample is currently composed of (around) 50000 firms. A major advantage of CADS is related to the fact that data undergo an accurate process of reclassification that ensures a good degree of comparability both across firms and time. However, the database does not include firms that have credit lines for an amount smaller than (about) 80,000 euros, that do not use their credit lines or that are insolvent, which may introduce an upward bias in the average creditworthiness of the firms belonging to CADS.

[15]The sample is stratified according to three criteria: sector, size and geographical location. With regard to the first criteria the two digits ATECO91 classification of the National Institute of Statistics (ISTAT) is adopted. Size dimension is proxied by the number of employees (four classes are evaluated: 50-99, 100-199,200-999, 1000+). Location refers to a regional (19) disaggregation. The stratification methodology adopted (optimal allocation to strata) implies that in SIM larger firms and firms located in the south of Italy are somehow overrepresented.

The Italian Credit Register (CR) is a database, housed at the Bank of Italy, which contains extensive information on loan contracts extended by Italian banks. All banks report information on credit granted and utilized for all loans in excess of a minimum threshold;[16] a subset of 80 banks also report the interest rate charged to individual borrowers, for different types of loans: commercial loans, personal loans, credit lines, foreign credit operations, collateralized loans, medium and long term loans. Due to changes in the degree of coverage, we are currently in a position to exploit CR only for a shorter time span, starting in 1989.

During the last two decades, SIM, CADS and CR have been extensively used to investigate a large number of disparate topics. Only in the last few years some authors have started exploiting the possibilities provided by their joint use. Guiso and Parigi (1999) merge data on capital stock, income and cash flow (CADS) with data on effective and planned investment and on expected demand (SIM) to investigate the effects of uncertainty on the investment decision of a sample of Italian manufacturing firms. Marchetti and Nucci (2001) use data on employment and hours, labor compensation, investment and capital stock (SIM) and use them together with information on sales, inventory change, purchases of intermediate goods (CADS) to obtain a measure of technological change that is not affected by any source of procyclical productivity. Marchetti and Nucci (2002) merge the two datasets to obtain detailed statistics on the typical frequency of price revision of a sample of Italian manufacturing firms and to investigate whether different degrees of price stickiness affect how a technological shock influences the use of the labor input in the production process. Guiso, Kashyap, Panetta and Terlizzese (2003) use data from CADS and CR to investigate how estimates of the interest sensitivity of investment depend on alternative measures of the marginal financing costs of the firm.

Information on individual price changes only exists in SIM since 1988. The complete sample of SIM over the period 1988 - 2001, after excluding a few firms that do not belong to the manufacturing sector, includes 2818 firms (16479 observations). Attrition related to the merging with CADS and missing values reduce the initial sample to a set of 2192 firms (9751 observations).[17] Our sample is fairly representative of firms with more than 50 employees according to the geographical and to the sectoral composition; however, it is slightly biased toward larger firms (Tables 3.2 to 3.4). Table 3.5 presents some basic statistics on the variables that are used in the empirical

[16] The threshold was set at 80 million lire (41,300 euro) until 1995, at 150 million lire thereafter. It is currently set at 75,000 euro.

[17] In Table 3.1 we report the number of observations in each of the years of the final sample.

analysis. The dependent variable, the firm level percent change in the price of output $\left(\dot{P}_{i,t}\right)$, is drawn from SIM, based on a specific question.[18] The aggregate behavior of this variable tracks closely its macro equivalent: the correlation between its annual sample mean and the annual change in output prices in manufacturing (ISTAT) is around 0.9 (Figure 3.1).

A first measure of the firm level interest rate $\left(r_{i,t}^{CR}\right)$ is obtained directly from bank data, as firm-specific lending rate on commercial borrowing and commercial paper discounted (CR), measured at end-year. This is an almost ideal variable for our purposes, as it matches the appropriate type of borrowing to finance working capital and it is measured quite precisely in the dataset. However, it is available over a shorter time interval than the rest of the sample (since 1989, or 1990 after taking first differences).[19]

As a robustness check, and to gain degrees of freedom, a second measure of the interest rate $\left(r_{i,t}^{CA}\right)$ is constructed by dividing total interest expenses by total financial debt (CADS). This measure has the advantage of being available for a larger number of firms and for a longer time horizon. However, being computed ex post from balance sheet data which aggregate a large number of liabilities of the firm, it is likely to be subject to measurement errors; moreover, unlike the previous measure, it aggregates the interest rate paid on all types of borrowing.

A third measure is the average policy interest rate $\left(r_t^P\right)$, i. e. the average annual Bank of Italy repo rate and the rate on ECB main refinancing operations since 1999. This variable is not firm-specific; the variable included in the regression retains cross-sectional variability entirely due by the terms the change in the interest rate is interacted with. When using this measure of the interest rate, the advantages of the micro-approach may be somehow diminished, although we may directly answer the question of the effects of policy moves on firms' pricing behavior. The three measures are used alternatively to check robustness of the results. Through time, they behave consistently with each other (Figure 3.2).

Net working capital is constructed using data from CADS, and it is defined, following Barth and Ramey (2002), as the value of inventories, plus commercial credit, less commercial debt. To obtain the ratio hi, we divide

[18] Firms are asked to report the percentage change in the average price of goods sold, together with the nominal change in sales. To check consistency of the responses, a control question asks to report the variation in sales in real terms.

[19] To control for outliers, we first deleted observations below the 5^{th} and above the 95^{th} percentiles of the distribution of the interest rate level; then applied the correction again to the first differences of resulting series $\left(\Delta r_{i,t}^{CR}\right)$. Extreme observations were similarly omitted in all firm-level variables.

net working capital by total operating costs, which are available in CADS;[20] firm averages are then taken across the whole period. Note that all results presented in this paper are fairly robust to the use of alternative definitions of this ratio (e. g., using total sales as the denominator). The mean of h (across firms and time) is equal to 0.33, i. e. firms keep four months of annual costs in the form of inventories.[21] Luckily for our research strategy, h_i displays a large cross-sectional variability, ranging from slightly below zero to 1.09 (Figure 3.3), thus effectively discriminating between firms with different working capital requirements.

As for the remaining variables, the variable $(1-\gamma_i)\,\dot{w}_{s,t}$ is constructed multiplying two-digit sectoral changes in contractual wages (ISTAT) by $(1-\gamma_i)$, with γ_i set equal to the firm-specific average ratio between input and service costs and total costs (CADS) (the sample mean of γ_i is around 0.76); similarly, the variable $\gamma_i\dot{v}_{s,t}$ is constructed multiplying two-digit sectoral log-changes in input prices (ISTAT) by γ_i.

The variable $(1-\gamma_i)\,U\dot{L}C_{i,t}$ is constructed by subtracting the log-change in real sales (SIM) from the nominal log-change in labor costs (CADS) and multiplying it by $(1-\gamma_i)$; similarly, the variable $\gamma_i U\dot{M}C_{i,t}$ is constructed by subtracting the log-change in real sales (SIM) form the log-change in material costs (CADS) and multiplying it by γ_i.

The variable $\left(\dot{y}_{i,t}-\gamma_i\dot{M}_{i,t}-(1-\gamma_i)\,\dot{N}_{i,t}\right)$ is constructed by subtracting from the log-change in real sales (source: SIM) the log-change in material input at constant prices (nominal total input cost deflated with sectoral input prices) and the log-change of labor input (change in average number of employees, source: CADS), appropriately weighted.

Finally, the firm level rate of capacity utilization ($CU_{i,t}$) is available in SIM as the answer to a specific question ("what is the ratio between actual production and the level of production which would be possible fully using the available capital goods without changing labor inputs?"). The correlation between the annual across-firm mean of this variable and a standard macro-measure of capacity utilization in manufacturing (computed by the Bank of Italy based on industrial production and quarterly surveys by ISAE) is equal to 0.78.

[20] In CADS, operating costs are defined as the sum of purchases of materials, intermediate and services, labor costs, interest expenses and depreciation allowances. In all cases when data on commercial credit and debit were missing, the ratio was computed as the inventory operating costs ratio (the estimates were not significantly affected).

[21] The average ratio to total sales is only marginally smaller, and equal to 0.32.

3.5 A Panel Estimation of the Cost-Channel

The fixed-effect estimates of equation (3.6) and (3.7) are respectively shown in Tables 3.6 and 3.7, where our three measures of interest rate changes ($r_{i,t}^{CR}$, $r_{i,t}^{CA}$ and r_t^P) are alternatively used as a regressor and time dummies are included. Time dummies control for all aggregate effects, including movements in demand, cyclical behavior of margins and, most notably for our purposes, traditional effects of monetary policy.[22] As a consequence, the estimates of a_4 - a_5 in equation (3.6) and b_3 - b_4 in equation (3.7) only capture firm-specific effects, and can be interpreted as directly measuring the cost effect of interest rate changes. If firms incur costs in financing working capital, the coefficient on the first interaction term (alternatively, $h_i \Delta r_{i,t}^{CR}$, $h_i \Delta r_{i,t}^{CA}$ and $h_i \Delta r_t^P$) should be positive and equal to one. If, in addition, firms have to anticipate labor costs, the coefficient on the second interaction term (alternatively, $(1-\gamma_i)\,\Delta r_{i,t}^{CR}$, $(1-\gamma_i)\,\Delta r_{i,t}^{CA}$ and $(1-\gamma_i)\,\Delta r_t^P$ should be positive and equal to the (assumed common) proportion of labor costs that are anticipated.

The results in Table 3.6 show that interest rate changes, when interacted with the working capital ratio, affect the firms price with a positive and highly significant coefficient, although its magnitude varies across the estimated regressions. In contrast, the coefficient on the second interaction term is usually not significantly different from zero (with one exception), indicating that the entire cost-channel effect is explained by the amount of working capital held by the firm, while the assumption that all firm have to finance the advance payment of labor cost in the same proportion is not unambiguously supported by the data. When the changes in the bank rate on short-term bank lending applied to each firm, measured at the beginning of the period, are used to construct the regressor ($h_i \Delta r_{i,t-1}^{CR}$, first and second columns), the corresponding coefficient is positive and statistically significant, although smaller than the unit value implied by equation (3.4). It is also positive and highly significant when the implicit average interest rate on firm's debt is used ($h_i \Delta r_{i,t}^{CA}$, third and fourth columns), although even smaller in absolute value. The coefficient is larger than in the previous cases, and not significantly different from 1, when the lagged change in the policy rate ($h_i \Delta r_{t-1}^P$, fifth and sixth columns) is used to construct the regressors.[23] In contrast, the

[22] The model was alternatively estimated with time dummies interacted with sector dummies, with no major difference in the results.

[23] Lagged levels of the policy rate are included, on the ground that it is likely to affect the average rate on the firms debt with a lag. In this case, of course, cross-sectional variability

estimates corresponding to coefficient a_4 are not statistically significant in two cases out of three (namely, when firm-specific measures of interest rates, $(1-\gamma_i)\,\Delta r^{CR}_{i,t-1}$ and $(1-\gamma_i)\,\Delta r^{CA}_{i,t}$ are used); the estimate is positive and significant only when aggregate $\left((1-\gamma_i)\,\Delta r^{CA}_{i,t}\right)$ interest rates are used. This evidence suggest that either firms do not incur costs in anticipating wages or that the share of labor costs that have to be anticipated is not common across firms as implied in deriving our equations. When this variable is omitted from the regression, the other estimates are not affected (this is done in columns 2, 4 and 6 of Table 3.6). The estimates of the remaining coefficients are to a large extent consistent with what was expected on the basis of equation (3.4). Price changes respond one-to-one (or more) to a change in input prices (the coefficient on $\gamma_i \dot{\nu}_{s,t}$ is always very close to 1), almost one-to-one to a change in wages (the coefficient on $(1-\gamma_i)\,\dot{w}_{s,t}$ is positive and highly significant, but somewhat smaller than one)[24] and positively to capacity utilization (the coefficient on $CU_{i,t}$ indicates that an increase in capacity utilization by 10 percent reduces the price of the firms output by about 60 basis points). Only the link to productivity is negative and highly significant, but quite small in absolute value.[25]

Table 3.7 shows the results from a corresponding battery of regressions based on equation (3.7), which uses firm-specific data on unit costs rather than sectoral wages and input prices. The estimates of the coefficient b_3 are remarkably robust across regressions and of the same order of magnitude as those in Table 3.6. The coefficient on the firm-level interest rates, when interacted with working capital, are still statistically different from zero and smaller than one (the point estimate is between 0.4 and 0.6), while the coefficients on the policy rate are also highly significant but not statistically different from 1. As before, the estimates of the coefficient b_4 are inconclusive (negative in one case, positive in a second case, not significantly different from zero in a third case). Capacity utilization still enters the price equation with the expected positive sign. The coefficients on the cost variables, unit labor cost $[(1-\gamma_i)\,\Delta ULC_{i,t}]$ and unit material cost $[\gamma_i \Delta UMC_{i,t}]$ are still positive and significant, although now much smaller than 1. The estimates of these coefficients may be downward biased due to measurement errors in the de-

in $h_i \Delta r^P_{t-1}$ only depends on h_i.

[24] Both findings resemble those obtained by Bils and Chang (2000) on US three-digit sectoral data.

[25] The coefficient is in absolute value smaller than the one estimated by Marchetti and Nucci (2002) for various productivity measures (their estimated coefficients are somewhere around -0.3). Bils and Chang (2000) also find that the impact of changes in TFP on the change in prices (our coefficient a_4) is less than one. For our purposes, the omission of this variable does not affect the estimates of the other coefficients.

pendent variables ULC, UMC, when obtained from balance sheet data. To our purposes, it is relevant that the estimates of the cost-channel effect are robust to the change in the specification.

All in all, our estimates of the cost-channel effect are consistent with the model presented in section 3.3, although the magnitude of the estimates is somewhat smaller than expected. A possible explanation is the relatively restrictive hypothesis adopted to go from equation (3.3) to equations (3.4) and (3.5), namely that firms instantaneously adjust prices to movements in marginal costs. In contrast with this assumption, a large theoretical and empirical literature argues that sticky price adjustment is an essential feature of market economies and that intervals between price revisions may sometimes be fairly large. In this environment firms would not set prices simply looking at current marginal cost, but at the discounted stream of expected future marginal cost.[26] In this case, the impact on prices of current marginal costs would be smaller than one, ceteris paribus; the same would hold for most explanatory variables on the right-hand side of equations (3.6) and (3.6), unless they also affect future expected marginal costs. Finding out whether this is the case is important, firstly, to assess whether smaller than expected estimates of the cost-channel effect, as in Table 3.6, signal a failure of the model presented in section 3.3, or they can rather be explained just by relaxing the assumption of instantaneous price adjustment.

To this end we exploit firm level information on the frequency of price adjustment available in SIM. This information stems from a specific question that was introduced in the 1996 survey. In that year the respondents were asked to provide an answer, choosing among five possible responses, to the question how frequently does your firm typically review selling prices?.[27] The survey results points to more frequent price adjustments than what has been found in other international studies; in our sample, about 70 percent of respondents declares to revise price at least every six months, and a third of them at least every three months.[28] To verify whether, when the estimation is restricted to firms which adjust their prices often, the estimated size of

[26] This is the case under the assumption of price adjustment á la Calvo.

[27] The admissible answers were: several times a month; every month; every 3 months; every 6 months; once a year or less frequently.

[28] Information on the frequency of actual price changes would be preferable as a measure of price stickiness. However, Blinder, Canetti, Lebow and Ruud (1998) and Hall (2000) document a strong positive correlation between the frequency of price revisions and the frequency of price changes. In the case of the SIM survey, the Bank of Italy interviewers reported that the re-examination of prices often coincided with their actual change; furthermore, Fabiani, Gattulli and Sabbatini (2003) conduct a survey on a different sample of Italian firms and confirm the close relationship between the frequency of price reviews and that of actual price changes.

some parameters is closer to what suggested by the theoretical model, we split the sample into two groups of firms. We interact all coefficients with a dummy variable D, taking value 0 for those firms who change prices at a frequency equal or higher than three months, 1 otherwise. The results are reported in Tables 3.8 and 3.9 . As expected, the adjustment of prices to most right-hand side variables is substantially smaller for those firms that adjust prices infrequently (the coefficients on variables interacted with D are mostly negative). This is not surprising, and it is to a large extent obvious. What is more interesting for our purposes is that the estimated coefficients for the frequently adjusting firms (those for which $D = 0$) now match much more closely the theoretical model. In particular, unlike the estimates in the previous section, the point estimate of the coefficient on the change of firm-level interest rates interacted with working capital is now quite close to one; the assumption that it is equal to one can be rejected only in one case. This evidence reinforces the conclusion that an effect on marginal costs is at work, whose size is entirely consistent with the implications of equation (3.4).

3.6 Is the Cost-Channel Effect Economically Relevant?

Is the cost-channel effect which we estimated economically - in addition to statistically - relevant? We can summarize our quantitative results as follows.

Firstly, our estimates suggest that over the whole sample the coefficient on the interaction variables $h_i \Delta r^{CB}_{i,t-1}$, $h_i \Delta r^{CA}_{i,t}$, $h_i \Delta r P_{t-1}$ in the price equation is between 0.3 and 1. Secondly, in our sample, h_i, the mean ratio of working capital to annual operating costs is around 0.33. On average, then, firms held four months worth of operating costs as working capital, which has to be financed. As a consequence, a one percent rise in (annualized) interest rates may induce an increase in prices between 10 and 30 basis points. Such an effect on prices, while not extraordinarily large, is not negligible. As a benchmark, in Italy, during the three main monetary restrictions in the period 1988 - 1998, the overall average policy rate increase was between 3 and 5.5 percentage points. This figures would imply an overall adverse effect on prices ranging from 0.3 to 1.6 percentage points, which would have partly counterbalanced the disinflationary effect operating through the demand side. While hardly enough to change the overall effect of monetary policy on prices over the medium run, this impact may not be irrelevant.

Is this effect enough to alter the optimal course that monetary policy should follow in response to various disturbances? A full answer goes beyond the scope of this paper, since it needs to be addressed in a general equilibrium framework. However, a tentative assessment can be offered by considering the implications of the model by Ravenna and Walsh (2003). That model incorporates the assumption that production costs have to be anticipated by one quarter, or, equivalently, that working capital is equal to one fourth of annual costs, and that its financing is entirely transferred into marginal costs. That assumption bears a close resemblance to the features of our sample: the average period over which costs have to be anticipated as working capital is slightly above one quarter, while the regressions in Table 3.7 show that the corresponding interest cost is fully reflected in marginal costs. In the Ravenna and Walsh model, under this assumption, and for a standard calibration of the remaining parameters, the appropriate policy response to shocks turns out to be affected; the cost-channel calls for a more gradual response to shocks than it would otherwise be (an illustration is in Appendix I).

3.7 Conclusions

We draw three implications from our study. Methodologically, using a unique dataset, we conclude that individual data on firms' pricing behavior give robust and direct evidence of the fact that monetary policy also works through the supply side; unlike previous results, we consider this evidence to be largely immune to the identification problem which plague the time-series literature. By observing the individual firms' pricing behavior we are also able to obtain a more reliable estimate of the magnitude of the cost-channel effect. Economically, we find the effect of interest rates on prices to be proportional to the ratio between working capital and sales, thus supporting the view that the cost-channel effect is intrinsically linked to the role of working capital in the production process of the firm, that is, in the end, to a mismatch between payments and receipts. This result is quite robust to alternative measures of firm-level interest rates from different sources. In contrast, we find little evidence of a separate interest rate effect related to the anticipation of wage payments, which is the assumption commonly adopted in the theoretical literature, in addition to what is already captured by the measure of working capital. From a normative point of view, the effect is economically significant; the adverse impact of interest rate hikes on the price level during a typical restriction cycle may not be negligible; the magnitude of the supply side effect is such to affect the optimal course of policy, possibly calling for more gradualism.

3.8 Appendix 3.I

In this Appendix, some policy implications of (a linearized version of) the model by Ravenna and Walsh (2003) are presented, in order to illustrate how, in a sticky-price, general equilibrium framework, the existence of a cost-channel can alter the optimal course of monetary policy in the face of various shocks.

$$\pi_t = \beta\pi_{t+1|t} + kmc_t + \omega_t \tag{3.8}$$
$$x_t = x_{t+1|t} + \sigma^{-1}\left(r_t - \pi_{t+1|t}\right) + \epsilon_t \tag{3.9}$$
$$mc_t = w_t - p_t + ar_t^Q \tag{3.10}$$
$$w_t - p_t = (\sigma + \phi)\, x_t \tag{3.11}$$
$$\omega_t = \rho_\omega \omega_{t-1} + o_t \tag{3.12}$$
$$\epsilon_t = \rho_\epsilon \epsilon_{t-1} + \upsilon_t \tag{3.13}$$
$$L_t = \left(\pi_t^2 + \lambda x_t^2\right) \tag{3.14}$$

where time t is measured in quarters, (π_t, mc_t, x_t, r_t^Q , $w_t - p_t$ are (quarter-on-quarter) inflation, the log-marginal cost of production, the log-output gap[29], the quarterly nominal interest rate and the real wage (all variables in deviation from steady state), ω_t, ϵ_t are respectively a cost-push and a demand shock, with an autoregressive structure, and L_t is the period loss function. We calibrate the model following broadly Ravenna and Walsh (2003): $\beta = 0.99$, $\phi = 1$, $k = 0.085$, $\sigma = 1.5$, $\lambda = 0.25$. For the sake of simplicity, we introduce the shocks ω_t, ϵ_t ad hoc, rather than derive them from microfoundations, and label them "cost-push" and "demand". We impose $\rho_\omega = \rho_\epsilon = 0.4$. The coefficient a measures the effect of the interest rate on marginal costs. Ravenna and Walsh set it equal to 1, based on the microeconomic assumption that all wages are paid one quarter in advance. Note that equation (3.10) can also be written in terms of the annualized interest rate $\left(r_t^A = 4r_t^Q\right)$, in which case the corresponding coefficient on this variable would be $a/4 = 0.25$ (this formulation is more directly comparable with our results in the main text). The central bank minimizes $\sum_{i=0}^{\infty} \beta_i L_{t+i}$. The optimal response of monetary policy to a unit innovation o_t (cost-push) or υ_t (demand) can be derived, as a function of the parameter a, both under commitment and under discretion, applying the procedure and the Matlab codes developed by Gerali and Lippi (2003). Figure 3.4 shows that, in the

[29]The output gap is defined as the deviation of output from its flexible price level. See Ravenna and Walsh (2003) for a precise definition in this setting.

case of a cost-push shock, when $a = 0$ the optimal policy under commitment consists in increasing interest rates moderately and gradually over time (continuous line)[30]; the central bank faces the usual trade-off between contrasting the increase in inflation and offsetting the fall in output. In sharp contrast, when the interest rate is allowed to affect marginal costs ($a = 1$), the optimal policy turns out to be an interest rate easing, even in the face of rising inflation (dotted lines). The intuition is simple: the central bank can in part offset the adverse cost-push shock by decreasing rates, thus relieving firms from interest expenses on their working capital. However, its ability to do so is limited by the adverse demand effect on prices, induced by an interest rate decrease. Under a fully discretionary policy (Figure 3.5), even when $a = 1$, the central bank has to rapidly increase interest rates to offset the effect of the cost-push shock on prices, as it cannot take advantage of the effect of its future behavior on inflation expectations. However, the increase is smaller when the cost-channel is present.

The optimal policy reaction after an expansionary demand shock is less affected by the cost-channel (Figure 3.6). When $a = 0$, policy is tightened in order to exactly offset the shock (disinflation is a free lunch). When $a = 1$, the monetary restriction must be somehow milder, because of its simultaneous adverse effects on supply. Since monetary policy has both supply and demand effects, it cannot exactly offset the consequences of a demand shock on prices without a cost in terms of output. However, the size of this effect is limited, at least for this calibration of the model.

3.9 Appendix 3.II

We define:

$$v'_t = v_t (1 + k_m r_t) \tag{3.15}$$
$$w'_t = w_t (1 + k_N r_t) \tag{3.16}$$

and, taking log changes (indicated by a dot on the top of a variable):

$$\dot{v}'_t = \dot{v}_t + \Delta \log (1 + k_m r_t) \cong \dot{v}_t + k_m \Delta r_t \tag{3.17}$$
$$\dot{w}'_t = \dot{w}_t + \Delta \log (1 + k_N r_t) \cong \dot{w}_t + k_N \Delta r_t \tag{3.18}$$

[30] The small size and the persistence of the interest rate increase is a standard consequence of the possibility of the central bank to commit, keeping expectations of future inflation under control.

We rewrite total cost as:

$$C_t = v'_t M_t + w'_t N_t + c_t K_t \tag{3.19}$$

The first order conditions of the cost minimization problem of the firm imply:

$$N_t = \left(A^{-1} y_t\right)^{\frac{1}{\delta+\alpha+\beta}} \left[\left(\frac{\beta c_t}{\alpha w'_t}\right)^{\alpha} \left(\frac{\beta v'_t}{\delta w'_t}\right)^{\delta} \right]^{\frac{1}{\delta+\alpha+\beta}} \tag{3.20}$$

$$K_t = \left(\frac{\alpha w'_t}{\beta c_t}\right) N_t \tag{3.21}$$

$$M_t = \left(\frac{\delta w'_t}{\beta v'_t}\right) N_t \tag{3.22}$$

From equation (3.21) we get:

$$\dot{N}_t + \dot{w}'_t = \dot{K}_t + \dot{c}_t \tag{3.23}$$

Total cost is given by :

$$\begin{aligned} C_t &= v'_t M_t + w'_t N_t + c_t K_t = \left[\frac{\alpha+\beta+\delta}{\beta}\right] w'_t N_t = \\ &= \left[\frac{\alpha+\beta+\delta}{\beta}\right] w'_t \left[\left(\frac{\beta c_t}{\alpha w'_t}\right)^{\alpha} \left(\frac{\beta v'_t}{\delta w'_t}\right)^{\delta} \right]^{\frac{1}{\delta+\alpha+\beta}} \left(A^{-1} y_t\right)^{\frac{1}{\delta+\alpha+\beta}} \\ &= (\alpha+\beta+\delta) \left[\left(\frac{c_t}{\alpha}\right)^{\alpha} \left(\frac{w'_t}{\beta}\right)^{\beta} \left(\frac{v'_t}{\delta}\right)^{\delta} \right]^{\frac{1}{\delta+\beta+\alpha}} \left(A^{-1} y_t\right)^{\frac{1}{\delta+\alpha+\beta}} \end{aligned} \tag{3.24}$$

The marginal cost and the log-change in the marginal cost are then given by:

$$MC_t = \frac{\partial C_t}{\partial y_t} = \left[\left(\frac{c_t}{\alpha}\right)^{\alpha} \left(\frac{w'_t}{\beta}\right)^{\beta} \left(\frac{v'_t}{\delta}\right)^{\delta} \right]^{\frac{1}{\delta+\beta+\alpha}} (A_t)^{-\frac{1}{\delta+\alpha+\beta}} (y_t)^{\frac{1}{\delta+\alpha+\beta}-1} \tag{3.25}$$

taking log differences of equation (3.24):

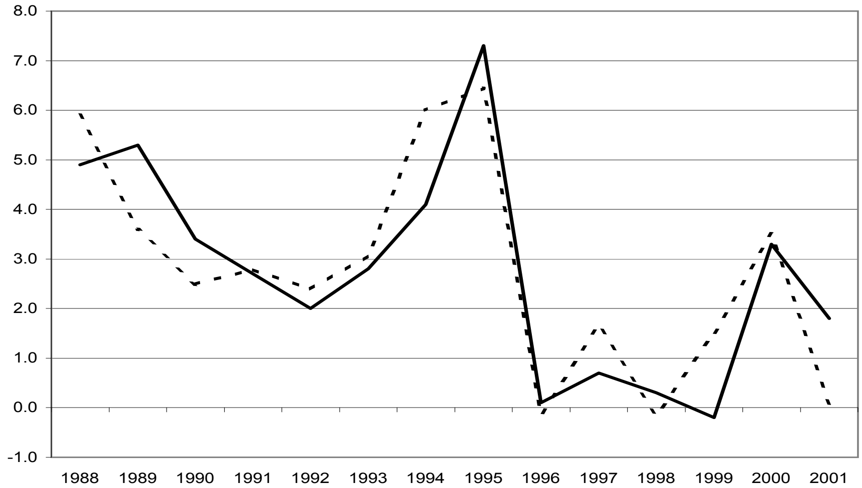
$$\begin{aligned} \dot{MC}_t &= \frac{\beta}{\delta+\alpha+\beta}\dot{w}'_t + \frac{\alpha}{\delta+\alpha+\beta}\dot{c}_t + \frac{\delta}{\delta+\alpha+\beta}\dot{v}'_t + \\ &\quad + \left(\frac{1}{\delta+\alpha+\beta} - 1\right)\dot{y}_t - \frac{1}{\delta+\alpha+\beta}\dot{A}_t \end{aligned} \tag{3.26}$$

Considering (3.23), this equation can be more conveniently written as:

$$\dot{MC}_t = \frac{\beta+\alpha}{\delta+\alpha+\beta}\dot{w}'_t + \frac{\delta}{\delta+\alpha+\beta}\dot{v}'_t + \left(\frac{1}{\delta+\alpha+\beta}\left(\dot{y}_t - \dot{A}_t\right) - \dot{y}_t\right) + \\ + \left(\frac{\alpha}{\delta+\alpha+\beta}\right)\left(\dot{N}_t - \dot{K}_t\right) \quad (3.27)$$

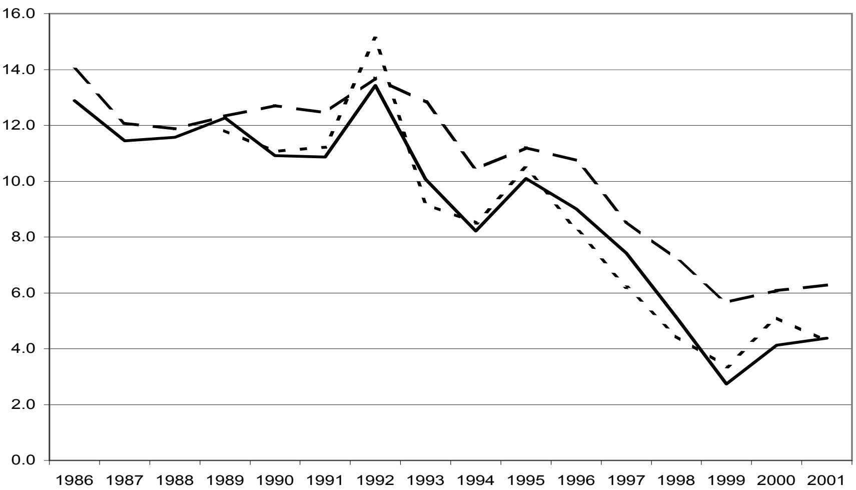
Considering that $\dot{y}_t = \dot{A}_t + \delta\dot{M}_t + \beta\dot{N}_t + \alpha\dot{K}_t$ and based on (3.17) and (3.18) , we obtain (3.3) in the text.

Figure 3.1: Aggregate versus Individual Prices



Solid line: Average firm-level price change in the sample. Dashed line: Aggregate change in the producer price index (excluding energy and food - source: ISTAT).

Figure 3.2: Aggregate versus Individual Interest Rates



Solid line: Firm level interest rate computed as the ratio between financial payments and financial debt (sample average). Dashed line: Policy rate (Bank of Italy's repo rate until 1998 and the rate on ECB main refinancing operations afterward). Dotted line: Firm level interest rate on bank borrowing (commercial credit discount, sample average).

Figure 3.3: Histogram: Firm Level Ratio between Working Capital and Total Costs (h_i)

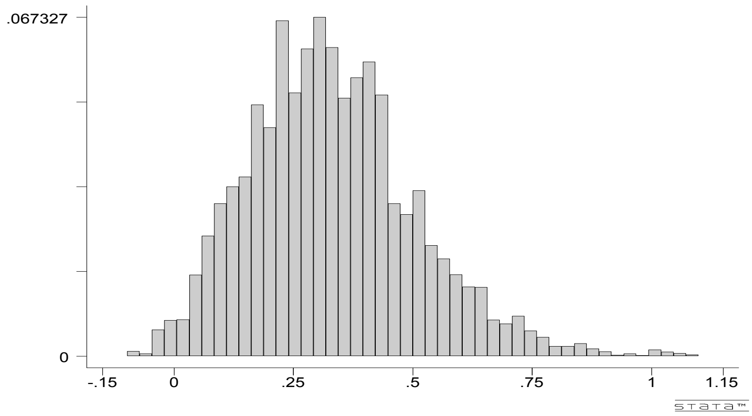
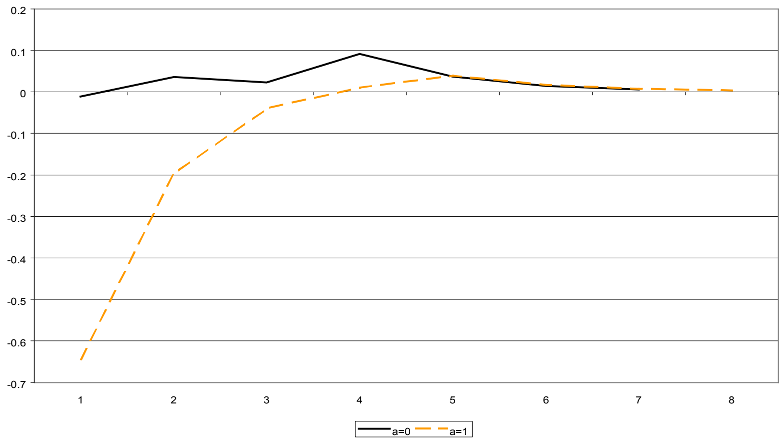
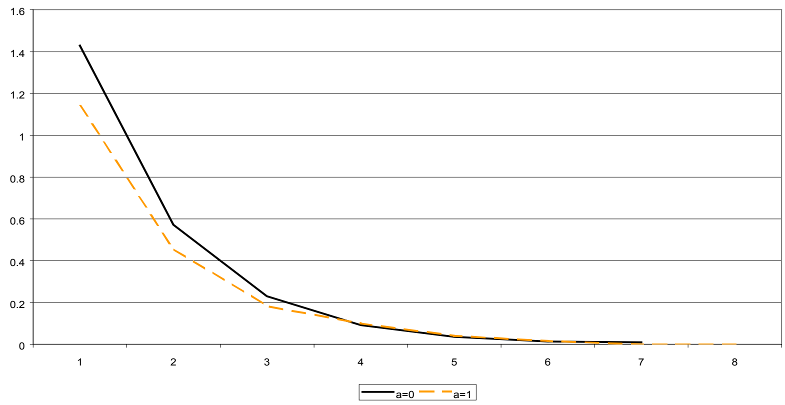


Figure 3.4: Optimal Interest Rate Response to a Cost-Push Shock under Commitment



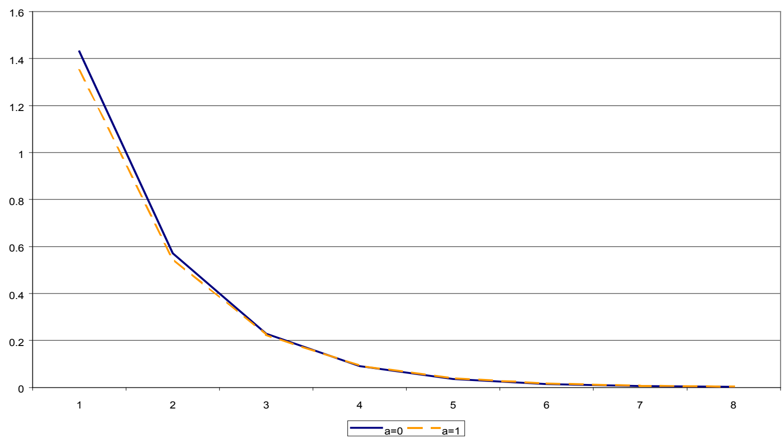
Optimal response of the interest rate to a unit cost-push shock (see the model in Appendix I). The parameter a measures the effect of the interest rate on marginal costs. $a = 0$ implies no cost-channel effect.

Figure 3.5: Optimal Interest Rate Response to a Cost-Push Shock under Discretion



Optimal response of the interest rate to a unit cost-push shock (see the model in Appendix I). The parameter a measures the effect of the interest rate on marginal costs; $a = 0$ implies no cost-channel effect.

Figure 3.6: Optimal Interest Rate Response to a Demand Shock under Commitment



Optimal response of the interest rate to a unit cost-push shock (see the model in Appendix I). The parameter a measures the effect of the interest rate on marginal costs; $a = 0$ implies no cost-channel effect.

Table 3.1: Number of observations per year

Year	Observations	Frequency
1988	521	5.3
1989	542	5.6
1990	541	5.6
1991	577	5.9
1992	596	6.1
1993	594	6.1
1994	626	6.4
1995	663	6.8
1996	748	7.7
1997	723	7.4
1998	766	7.9
1999	781	8.0
2000	1024	10.5
2001	1049	10.8
Total	9751	100.0

Table 3.2: Total sample composition according to geographical location

	North-West	North-East	Center	South and Isl.	Total
Observations	4086	2467	1783	1415	9751
Frequency	41.9	25.3	18.3	14.5	100.0
Population	44.5	30.4	14.9	10.3	100.0

Note: The source for the distribution of the population of firms is ISTAT. In 1995 the number of firms in manufacturing with more than 50 employees was equal to 10881. In 1996 the total number of manufacturing firms was 551,000, those with more than 50 employees were 11453, the annual average number of firms in our sample is equal to 697.

Table 3.3: Total sample composition according to number of employees

	50-99	100-199	200-499	500-999	1000+	Total
Observations	2336	2511	2736	1212	956	9751
Frequency	24.0	25.8	28.1	12.4	9.8	100.0
Population	55.6	26.3	13.2	3.0	1.9	100.0

Note: The source for the distribution of the population of firms is ISTAT. In 1995 the number of firms in manufacturing with more than 50 employees was equal to 10881. In 1996 the total number of manufacturing firms was 551,000, those with more than 50 employees were 11453, the annual average number of firms in our sample is equal to 697.

Table 3.4: Total sample composition according to sector

	Textile, Clothes, Leather, Shoes	Chemical, Rubber, Plastic	Metals, Machinery	Other Manufacturing	Total
Observations	1979	1233	3743	2796	9751
Frequency	20.3	12.6	38.4	28.7	100.0
Population	21.0	10.8	41.8	26.4	100.0

Note: The four sectors reported in table 3.4 have been obtained aggregating two digit ATECO91 sub-sectors. "Textile, clothes, leather and shoes" corresponds to sub-sectors DB and DC, "Chemical, rubber and plastic" to sub-sectors DF, DG and DH, "Metals and machinery" to sub-sectors DJ, DK, DL and DM, "Manufacturing: others" to all the remaining manufacturing sectors. The source for the distribution of the population of firms is ISTAT. In 1995 the number of firms in manufacturing with more than 50 employees was equal to 10881. In 1996 the total number of manufacturing firms was 551,000, those with more than 50 employees were 11453, the annual average number of firms in our sample is equal to 697.

Table 3.5: Descriptive statistics

	N	Mean	Std.Dev.	10%	25%	50%	75%	90%
$\dot{P}_{i,t}$	9751	2.55	6.25	-3.00	0.00	2.50	5.00	8.00
$CU_{i,t}$	9670	80.72	12.52	65.00	75.00	81.00	90.00	95.00
γ_i	9751	0.76	0.11	0.61	0.70	0.77	0.84	0.89
$\dot{w}_{s,t}$	9751	3.82	2.42	1.71	2.04	3.10	5.53	6.06
$U\dot{L}C_{i,t}$	7934	3.00	30.59	-13.29	-5.73	1.21	9.20	18.79
$\dot{v}_{s,t}$	9751	3.10	3.76	-0.71	0.82	3.07	4.85	6.92
$U\dot{M}C_{i,t}$	7933	5.51	72.62	-15.54	-5.87	2.85	12.26	24.30
$pr\dot{o}d_{i,t}$	7775	2.88	14.44	-10.79	-3.93	2.32	9.09	17.54
h_i	9719	0.33	0.17	0.12	0.21	0.32	0.43	0.56
$\Delta r^{CR}_{i,t-1}$	3741	-0.65	2.49	-3.46	-1.96	-0.84	1.09	2.34
$h_i\Delta r^{CR}_{i,t-1}$	3741	-0.22	0.95	-1.21	-0.65	-0.22	0.25	0.90
$\Delta r^{CA}_{i,t}$	6062	-0.39	3.16	-4.55	-2.25	-0.22	1.55	3.51
$h_i\Delta r^{CA}_{i,t}$	6056	-0.14	1.20	-1.53	-0.70	-0.05	0.46	1.19
Δr^{P}_{t-1}	9751	-0.66	1.71	-2.39	-1.86	-1.37	0.70	1.88
$h_i\Delta r^{P}_{t-1}$	9719	-0.22	0.64	-0.99	-0.63	-0.25	0.20	0.60

Table 3.6: The price equation I

$(1-\gamma_i)\,\dot{w}_{s,t}$	0.802**	0.801**	0.664**	0.667**	0.628**	0.623**
	(0.287)	(0.286)	(0.215)	(0.215)	(0.179)	(0.179)
$\gamma_i \dot{v}_{s,t}$	1.351**	1.351**	0.957**	0.956**	0.929**	0.930**
	(0.060)	(0.060)	(0.045)	(0.045)	(0.040)	(0.040)
$\dot{prod}_{i,t}$	-0.090**	-0.090**	-0.080**	-0.080**	-0.074**	-0.074**
	(0.008)	(0.008)	(0.006)	(0.006)	(0.005)	(0.005)
$h_i \Delta r^{CR}_{i,t-1}$	0.478**	0.529**				
	(0.242)	(0.198)				
$(1-\gamma_i)\,\Delta r^{CR}_{i,t-1}$	0.127					
	(0.350)					
$h_i \Delta r^{CA}_{i,t}$			0.383**	0.233**		
			(0.137)	(0.065)		
$(1-\gamma_i)\,\Delta r^{CA}_{i,t}$			-0.240			
			(0.193)			
$h_i \Delta r^{P}_{i,t-1}$					0.682**	0.939**
					(0.240)	(0.232)
$(1-\gamma_i)\,\Delta r^{P}_{i,t-1}$					1.470**	
					(0.363)	
$CU_{i,t}$	0.054**	0.054**	0.057**	0.057**	0.061**	0.060**
	(0.013)	(0.013)	(0.009)	(0.009)	(0.008)	(0.008)
R^2	0.31	0.31	0.24	0.24	0.24	0.23
Observations	3654	3654	5940	5940	7709	7709
Firms	904	904	1443	1443	1652	1652

Note: Fixed effects estimation. Time effects included. The variables are those defined in equation (3.4) in the main text. A subscript i denotes a firm-level variable, a subscript s a (two-digit) sectoral variable and a subscript t denotes a variable that varies over time. (**) denotes a parameter that is significant at a 5 per cent confidence level, (*) a parameter that is significant at a 10 per cent confidence level.

Table 3.7: The price equation II

$(1-\gamma_i)\, U\dot{L}C_{i,t}$	0.138**	0.138**	0.178**	0.181**	0.158**	0.160**
	(0.031)	(0.031)	(0.022)	(0.022)	(0.018)	(0.018)
$\gamma_i U\dot{M}C_{i,t}$	0.210**	0.210**	0.183**	0.183**	0.167**	0.168**
	(0.009)	(0.009)	(0.006)	(0.006)	(0.005)	(0.005)
$h_i \Delta r^{CR}_{i,t-1}$	0.580**	0.565**				
	(0.238)	(0.194)				
$(1-\gamma_i)\, \Delta r^{CR}_{i,t-1}$	-0.037					
	(0.341)					
$h_i \Delta r^{CA}_{i,t}$			0.581**	0.365**		
			(0.133)	(0.063)		
$(1-\gamma_i)\, \Delta r^{CA}_{i,t}$			-0.346*			
			(0.186)			
$h_i \Delta r^{P}_{i,t-1}$					0.781**	0.942**
					(0.231)	(0.223)
$(1-\gamma_i)\, \Delta r^{P}_{i,t-1}$					0.914**	
					(0.357)	
$CU_{i,t}$	0.038**	0.038**	0.050**	0.051**	0.050**	0.050**
	(0.013)	(0.013)	(0.009)	(0.009)	(0.008)	(0.008)
R^2	0.31	0.31	0.28	0.28	0.27	0.27
Observations	3686	3686	5939	5939	7725	7725
Firms	909	909	1445	1445	1651	1651

Note: Fixed effects estimation. Time effects included. The variables are those defined in equation (3.5) in the main text. A subscript i denotes a firm-level variable, a subscript s a (two-digit) sectoral variable and a subscript t denotes a variable that varies over time. (**) denotes a parameter that is significant at a 5 per cent confidence level, (*) a parameter that is significant at a 10 per cent confidence level.

Table 3.8: The frequency of price adjustment and the cost-channel

$(1-\gamma_i)\,\dot{w}_{s,t}$	0.761	1.288**	1.135**
	(0.546)	(0.459)	(0.393)
D $(1-\gamma_i)\,\dot{w}_{s,t}$	-0.019	-1.128**	-0.763
	(0.670)	(0.553)	(0.468)
$\gamma_i \dot{v}_{s,t}$	1.676**	1.035**	1.021**
	(0.090)	(0.067)	(0.061)
D $\gamma_i \dot{v}_{s,t}$	-0.952**	-0.474**	-0.446**
	(0.128)	(0.098)	(0.087)
$h_i \Delta r^{CR}_{i,t-1}$	0.891**		
	(0.351)		
D $h_i \Delta r^{CR}_{i,t-1}$	-0.533		
	(0.435)		
$h_i \Delta r^{CA}_{i,t}$		0.722**	
		(0.144)	
D $h_i \Delta r^{CA}_{i,t}$		-0.656**	
		(0.167)	
$h_i \Delta r^{P}_{i,t-1}$			2.120**
			(0.467)
D $h_i \Delta r^{P}_{i,t-1}$			-1.383**
			(0.563)
$CU_{i,t}$	0.122**	0.083**	0.098**
	(0.025)	(0.019)	(0.017)
D $CU_{i,t}$	-0.093**	-0.050**	-0.062**
	(0.030)	(0.023)	(0.020)
$\dot{prod}_{i,t}$	-0.158**	-0.125**	-0.117**
	(0.015)	(0.010)	(0.009)
D $\dot{prod}_{i,t}$	0.109**	0.071**	0.066**
	(0.018)	(0.014)	(0.011)
R^2	0.37	0.30	0.29
Observations	2988	4215	5425
Firms	583	702	755

Note: Fixed effects estimation. Time effects included. The variables are those defined in equations (3.4) in the main text. A subscript i denotes a firm-level variable, a subscript s a (two-digit) sectoral variable and a subscript t denotes a variable that varies over time. (**) denotes a parameter that is significant at a 5 per cent confidence level, (*) a parameter that is significant at a 10 per cent confidence level. The dummy variable D is equal to 1 for those firms whose frequency of price review is equal or smaller than 3 months, equal to 0 otherwise. The D dummy has been also interacted with time effects.

Table 3.9: The frequency of price adjustment and the cost-channel

$(1-\gamma_i)\,U\dot{L}C_{i,t}$	0.299**	0.327**	0.263**
	(0.061)	(0.047)	(0.041)
D $(1-\gamma_i)\,U\dot{L}C_{i,t}$	-0.225**	-0.197**	-0.113**
	(0.072)	(0.055)	(0.048)
$\gamma_i U\dot{M}C_{i,t}$	0.325**	0.324**	0.297**
	(0.014)	(0.011)	(0.010)
D $\gamma_i U\dot{M}C_{i,t}$	-0.215**	-0.225**	-0.197**
	(0.018)	(0.015)	(0.013)
$h_i\Delta r^{CR}_{i,t-1}$	0.814**		
	(0.336)		
D $h_i\Delta r^{CR}_{i,t-1}$	-0.412		
	(0.415)		
$h_i\Delta r^{CA}_{i,t}$		0.967**	
		(0.133)	
D $h_i\Delta r^{CA}_{i,t}$		-0.821**	
		(0.155)	
$h_i\Delta r^{P}_{i,t-1}$			1.499**
			(0.433)
D $h_i\Delta r^{P}_{i,t-1}$			-0.732
			(0.524)
$CU_{i,t}$	0.084**	0.071**	0.090**
	(0.024)	(0.017)	(0.016)
D $CU_{i,t}$	-0.063**	-0.039*	-0.056**
	(0.028)	(0.021)	(0.019)
R^2	0.41	0.39	0.36
Observations	3012	4215	5449
Firms	584	703	755

Note: Fixed effects estimation. Time effects included. The variables are those defined in equations (3.5) in the main text. A subscript i denotes a firm-level variable, a subscript s a (two-digit) sectoral variable and a subscript t denotes a variable that varies over time. (**) denotes a parameter that is significant at a 5 per cent confidence level, (*) a parameter that is significant at a 10 per cent confidence level. The dummy variable D is equal to 1 for those firms whose frequency of price review is equal or smaller than 3 months, equal to 0 otherwise. The D dummy has been also interacted with time effects.

Chapter 4

Heterogeneous Effects of Monetary Policy on Inventory Investment

4.1 Introduction

It is a well known fact that, at least in the short run, monetary policy can significantly affect the evolution of the real economy (Romer and Romer (1989), Bernanke and Blinder (1992) and Christiano, Eichenbaum and Evans (1996)). There is far less agreement, however, about how exactly monetary policy exerts its influence. During the sixties and the seventies most of the theoretical and empirical analysis were based on the liquidity-channel. According to this transmission mechanism the monetary authority, by controlling the amount of real money in the economy, is able to affect interest rates and, in turn, interest sensitive components of aggregate spending. Yet empirical studies based on this theory have encountered great difficulties in identifying a quantitatively important effect of the neoclassical cost of capital variable (Bernanke and Gertler (1995) and Bernanke, Gertler and Gilchrist (1998)). Therefore some researchers have started to analyze the problem from new perspectives trying to find theoretical reasons and empirical evidence in favor of the existence of some other channels through which monetary policy could affect the real evolution of the economy.

Two theories that have obtained a lot of consensus are the lending-channel theory and the and balance sheet-channel theory. While the former focuses on the possible effects of monetary policy on the ability of banks to supply funds, the latter analyzes the possibility that a variation in the interest rate level could affect the wealth of a firm and, in turn, the conditions at which it can obtain external funds. Both positions have strong theoretical support. However, as many of the empirical analysis have produced conflicting results, their practical relevance is still debated. A key implication of these new theories is the fact that the effect of monetary policy on firms' decisions might depend on a set of individual characteristics like the size, the level of indebtedness or the age. As a consequence the empirical tests of these theories have systematically been based on a preliminary partitioning of, supposedly, more sensitive firms from less sensitive ones. In particular according to the lending channel firms that make a larger use of banks' funds should be those more exposed to contractions in the availability of credit. On the other side, according to the balance sheet channel, small and young firms that are likely to be subject to more relevant asymmetric information problems should be those more exposed to a weakening in their financial position. Such segmentation is usually assumed to be unique[1] and the threshold is normally arbitrarily selected.

The lack of a common criteria in the selection of the number of groups and of the cutting points has give rise to a large number of empirical works whose results, being based on different assumptions, cannot be compared. Just to make a few examples Gertler and Gilchrist (1994) find differences in the cyclical behavior of small and large manufacturing U.S. firms and in their responses to monetary policy shocks by dividing the complete sample of firms in two groups and adopting as a break point the threshold of 25 millions of dollars of nominal total assets.[2] Hubbard, Kashyap and Whited (1995) divide small from large firms using capital stock as a ordering criteria and adopting as a cutoff level the 25^{th} percentile of their empirical distribution. Using these criteria they fail to find heterogeneities between small and large firms in the reaction of investment to cash flow and credit conditions. Also the analysis of Gilchrist and Himmelberg (1998) that investigates the relevance of capital market imperfections on investment policies is based on sample splittings. They find a strong response of small firms' investment to financial factors once firms are divided into small and large ones adopting as a ordering criteria the amount of real sales and as a splitting point the 66^{th} percentile of the empirical distribution.[3] More recently Bagliano and Sembenelli (2003) employ a panel of European firms to study the effect of the recession of the

[1]That is it is based on the assumption that the universe of firms can be subdivided in only two group of firms.

[2]The source for their data is the *Quarterly Financial Report for Manufacturing Corporations* that provides quarterly profit and loss and balance sheet information for eight different nominal asset size classes.

[3]This threshold is equivalent to 365 millions of 1992 dollars and is substantially different from that used by Gertler and Gilchrist (1994)).

early '90s on inventory investment, controlling for cyclical fluctuations at the firm level. In order to capture differential financial market access, and consequently different sensitivities to credit market conditions, they partition the sample of firms according to the level of sales in 1990 in two groups (small and large) using as a threshold the amount of 20 millions of ECU. It is already evident from these few examples that the lack of a well founded criteria for the selection of the number of groups and of the cutoff points has generated a large number of results whose reliability is, at least, questionable.

The main objective of this chapter is to use a new methodology (Canova (2004)) that, exploiting data predictive density, allows to detect clusters according to a statistically based criteria. The methodology is implemented in two steps. First the sensitivity to monetary policy shocks at a firm level is estimated. Then, after having ordered firms according to some exogenous criteria (e.g. the level of sales or the number of employees), we verify whether the empirical distribution of individual estimated sensitivities to monetary policy shocks provides evidence in favor of the existence of clusters. The search for clusters is performed according to a maximum likelihood principle. Groups that emerge distinguish each other according to two characteristics. First, there might be heterogeneity in the average effect of monetary policy (i.e. there estimated average effects across groups are different) or, second, there might be heterogeneity in the degree of within group dispersion of the estimated effects (i.e. the dispersions of the firm level estimated effects around the estimated average effect of the group are different across groups).

The empirical analysis is focused on Italian manufacturing firms and, in particular, on the response of inventory investment to monetary policy shocks from 1983 to 1998. The main source of the data used in this work is the *Company Accounts Data Service* (CADS) from which we have obtained detailed firm level informations on the balance sheet structure and on the profits and losses account for around 4,000 firms over the sample 1983-1998.

The main results that emerge from the analysis are the following. Most of the orderings give rise to a number of classes that is larger than two. Orderings based on variables that are normally thought to be equivalent proxies for the size of the firm (turnover, total assets and number of employees) do not lead neither to the same number of groups nor to similar splitting points. Even if endogenous clusters are mainly characterized by different degrees of within group heterogeneity,[4] there also exist important differences in the average effect of monetary policy across groups. In particular the fact that some of the orderings do not show the expected monotonicity between rank and average effect appears to be one of the most remarkable aspects. For

[4] Groups composed by smaller firms show, in general, the largest dispersion.

example firms with a number of employees between 25 and 50 turn out to be less sensitive to monetary policy shocks than firms that have less than 25 employees as well as than those that have more than 50 employees. Similarly firms that have a leverage between 0.7 and 0.8 result to be more responsive to monetary innovations than firms that are less or more leveraged.

The econometric methodology is described in section 4.2. The specification of the inventory equation, the dataset and the results of the OLS regressions are presented in section 4.3. In section 4.4 we select a distribution function for the clustering analysis and we derive the algorithm to be used for the estimation of the number of groups and their specific parameters. The main results are presented in section 4.4.3. Section 4.5 concludes.

4.2 Clustering: The Econometric Methodology

The clustering analysis is based on the belief that there are heterogeneities in the cross sectional data and that there is a natural clustering of units, in the sense that the parameters of the statistical model are more similar within than across groups. The setup of the statistical model is based on the assumption that it is not known which ordering of the cross sectional units will naturally generate the clustering we are looking for. Let N be the size of the cross section, T the size of the temporal dimension and $m = 1, 2, ..., N!$ be a particular ordering of the units of the cross section. We believe that there may be $q = 1, 2, ..., Q$ breaks in the cross section and we assume that for each of the resulting $q + 1$ groups the data set can be described as:

$$Y_{i,t} = \boldsymbol{X}_i \boldsymbol{\beta}_i + u_{i,t,p} \tag{4.1}$$

$$i = 1, ..., n^p(m) \qquad t = 1, ..., T \tag{4.2}$$

where $n^p(m)$ is the cross section dimension of group p conditional on ordering m.

$$p = 1, ..., q + 1 \tag{4.3}$$

$$\boldsymbol{\beta}_i = \boldsymbol{\beta}^p + \boldsymbol{\epsilon}_i^p \tag{4.4}$$

$$\boldsymbol{u}_p \sim (0, \boldsymbol{\Sigma}_{u,p}) \qquad \boldsymbol{\epsilon}^p \sim (0, \boldsymbol{\Sigma}_{\epsilon,p}) \tag{4.5}$$

As proposed by Canova (2004) it's possible to provide a framework for testing the hypothesis that there are heterogeneities in the cross section dimension in a situation where the number of break points q, their locations and the permutation m, which naturally leads to the clustering, are unknown and also to estimate the hyper-parameters $(\boldsymbol{\beta}^p, \boldsymbol{\Sigma}_{\epsilon,p})$ for each group $p = 1, ..., q+1$. Let $\boldsymbol{Y}$ be the $(N \cdot T) \times 1$ vector of the left hand side of (4.1) ordered to have the N cross sections for each $t = 1, ..., T$, $\boldsymbol{X}$ be the $(N \cdot T) \times (N \cdot K)$ matrix of regressors, $\boldsymbol{\beta}$ be the $(N \cdot K) \times 1$ vector of coefficients of the model, $\boldsymbol{u}$ the $(N \cdot T) \times 1$ vector of disturbances, $\boldsymbol{\beta}_0$ the $(q+1) \cdot K \times 1$ vector of hyper-parameters $\boldsymbol{\beta}^p$, $\boldsymbol{A}$ be a $(N \cdot K) \times (q+1) \cdot K$ matrix with $\boldsymbol{A} = diag\{\boldsymbol{A}_p\}$ and where $\boldsymbol{A}_p$ has the form $\boldsymbol{\iota}_p \otimes \boldsymbol{I}_K$ ($\boldsymbol{I}_K$ is a $(K \times K)$ identity matrix and $\boldsymbol{\iota}_p$ is a $n^p(m) \times 1$ vector of ones). For each permutation m of the units of the cross section, we can rewrite equations (4.1) to (4.5) more compactly as:

$$\boldsymbol{Y} = \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{u} \qquad \boldsymbol{u} \sim (\boldsymbol{0}, \boldsymbol{\Sigma}_u) \tag{4.6}$$

$$\boldsymbol{\beta} = \boldsymbol{A}\boldsymbol{\beta}_0 + \boldsymbol{\epsilon} \qquad \boldsymbol{\epsilon} \sim (\boldsymbol{0}, \boldsymbol{\Sigma}_\epsilon) \tag{4.7}$$

where the dimension of $\boldsymbol{\Sigma}_u$ is $(N \cdot T) \times (N \cdot T)$ and $\boldsymbol{\Sigma}_\epsilon = diag\{\boldsymbol{\Sigma}_{\epsilon,p}\}$ is a $(N \cdot K) \times (N \cdot K)$ matrix. Substituting (4.7) in (4.6) we get:

$$\boldsymbol{Y} = \widetilde{\boldsymbol{X}}\boldsymbol{\beta}_0 + \boldsymbol{w} \qquad \boldsymbol{w} \sim (0, \boldsymbol{\Sigma}_w) \tag{4.8}$$

where $\widetilde{\boldsymbol{X}} = \boldsymbol{X} * \boldsymbol{A}$ and $\boldsymbol{w} = \boldsymbol{X}\boldsymbol{\epsilon} + \boldsymbol{u}$. To grasp the intuition of the following steps assume for the moment that, given an ordering m and a set of q cut points, we are able to estimate the hyper-parameters $\boldsymbol{\beta}_0$ and $\boldsymbol{\Sigma}_\epsilon$, and $\boldsymbol{\Sigma}_u$ that maximize the predictive density of the data. Under this assumption we are able to compute the maximum level of $L(\boldsymbol{Y}|H_0, m)$, that is the maximum of the likelihood function under the assumption that the hyper-parameters of the model are the same in each subgroup.[5] Similarly we can also maximize $L(\boldsymbol{Y}|H_q, n^p(m), m) = \prod_{p=1}^{q+1} L(\boldsymbol{Y}^p|H_q, n^p(m), m)$, that is the maximum of the likelihood function under the assumption that there are q break points. We define the following quantities: $L^+(\boldsymbol{Y}|H_q, m)$, $L^\dagger(\boldsymbol{Y}|H_q)$ and $L^{A_q}(\boldsymbol{Y}|H_q, m)$.

$$L^+(\boldsymbol{Y}|H_q, m) = \sup_{i_q \in I_q} L(\boldsymbol{Y}|H_q, i_q, m) \tag{4.9}$$

where i_q is an element of the set of all the possible locations of the q break points I_q. For a given ordering of the data m and a given number of break

[5]That is $\boldsymbol{\beta}_0 = \boldsymbol{\iota} \otimes \overline{\boldsymbol{\beta}}$ where $\boldsymbol{\iota}$ is a (q + 1) $\times$ 1 vector of ones and $\overline{\boldsymbol{\beta}}$ is a K $\times$ 1 vector and $\boldsymbol{\Sigma}_{\epsilon,p} = \overline{\boldsymbol{\Sigma}}$, $\forall p$.

points q, L^+ is the maximized value of the predictive density with respect to the location of the break points.

$$L^{\dagger}\left(\boldsymbol{Y}\left|H_q\right.\right) = \sup_{j \in J} L^{+}\left(\boldsymbol{Y}\left|H_q, j\right.\right) \tag{4.10}$$

where j is one of the $N!$ orderings in J. $L^{\dagger}$ provides the maximized value of the predictive density L^+ with respect to the ordering j.

$$L^{A_q}\left(\boldsymbol{Y}\left|H_q, m\right.\right) = \sum_{i_q \in I_q} \pi_{i_p} L\left(\boldsymbol{Y}\left|H_p, i, m\right.\right) \tag{4.11}$$

where π_{i_p} is the prior probability of the event that the location of splitting points is i_p. L^{A_q} gives the average likelihood of the data under the assumption that there are q breaks, where the average is calculated over all possible locations of break points i_p.[6] To examine the hypothesis that there are heterogeneities in the cross sectional dimension of the panel one can use either a posterior odds ratio or a montecarlo approach. We start describing the approach based on the posterior odds ratio. According to a posterior odds ratio criteria tests are implemented sequentially[7] starting from the null that there are no break points against the alternative that there are at most Q breaks. Then, if the null is rejected, we sequentially test a series of hypotheses where the null is that there are q break points and the alternative that there are $q+1$ break points ($q+1 \leq Q$) until all the groups are discovered. Given an ordering m of the data, the posterior odds ratio for the first hypothesis is given by:

$$PO\left(m\right) = \frac{\sum_{q=1}^{Q} \pi_q L^{A(q)}\left(\boldsymbol{Y}\left|H_q, m\right.\right)}{\pi_0 L\left(\boldsymbol{Y}\left|H_0, m\right.\right)} \tag{4.12}$$

where π_0 and π_q are prior probabilities that there are no breaks and that there are q breaks. We reject H_0 when $PO\left(m\right) > e^{0.5\log\left(N\right)}$.[8] The statistic for testing the null hypothesis that there are q breaks in the cross section against the alternative of $q+1$ groups is:

$$PO\left(m, q\right) = \frac{\pi_{q+1} L^{A(q+1)}\left(\boldsymbol{Y}\left|H_{q+1}, m\right.\right)}{\pi_q L^{+}\left(\boldsymbol{Y}\left|H_q, m\right.\right)} \tag{4.13}$$

[6]In general ignorance about the location of break points leads to assume $\pi_{i_p} = \overline{\pi}, \forall i_p$.

[7]Bai (1997) shows that proceeding sequentially in testing for breaks produces consistent estimates of the parameters of the model and of the break points.

[8]The value of the right hand side of the inequality might be shown to be equivalent the one employed by the Schwartz approximation to the PO ratio and assigns equal prior probability to the null and the alternative. This is the same value adopted by Canova (2004).

also in this case we reject the null when $PO\,(m,q) > e^{0.5\log(N)}$. Such a sequential procedure allow us, given an ordering m of the cross section, and the maximum number Q of break points which may exists, to examine how many groups there actually are. To find the location of the break point given q, we select the number of units in each partition so as to provide the highest total likelihood for the data, i.e. we compute $L^{+}\left(\boldsymbol{Y}\,|H_q, m\right)$. Since in the empirical part of the paper we are interested in verifying the existence of heterogeneity when data are ordered according to well specified exogenous criteria (e.g. the amount of sales, the amount of assets or the number of employees) we do not present the statistics that are necessary to test for the existence of groups when the cross sectional ordering is not know. Refer to Canova (2004) for details on this part.

The alternative montecarlo approach is based on the hypothesis that the cross section dimension of our sample is sufficiently large to be used, in a sense that will be clear in a while, as a proxy for the population. In this case the null hypothesis that, given an ordering m there is a break point at i_1 against the alternative that there are no breaks, can be tested at a confidence level of z per cent by verifying that $L^{+}\left(\boldsymbol{Y}\,|H_1, i_1, m\right)$ is larger than z per cent of the values of the likelihood evaluated with a break at i_1 after permuting the initial ordering m until the percentiles of the distribution of the $L\left(\boldsymbol{Y}\,|H_1, i_1, m'\right)$ (with $m' \in M'$ and M' is the set of $N!$ possible permutations) stabilizes.[9] Since our sample is composed of, around, 4000 units we believe that the information extracted from the alternative orderings (i.e. those in M') can be used as a valid benchmark for the alternative hypothesis.[10] We therefore start by testing the hypothesis of two groups against the alternative of homogeneity among observations according to the following steps:

i. For a given ordering (e.g. sales), we evaluate the likelihood at each possible splitting point and we select as candidate optimal break point (i_1) the splitting point that attains the maximum level of the likelihood.

ii. Next we randomly permute the initial ordering a sufficiently large number of times and, for each permutation, we store the likelihood attained when we split the sample at (i_1).[11] This allows to compute percentiles of the distribution of likelihoods obtained at i_1 for different initial ordering of the cross section of the data.

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[9]Note that for each permutation m' we compute the values of the hyper-parameters that maximize $L\left(\boldsymbol{Y}\,|H_1, i_1, m'\right)$.

[10]Note that even with only 10 individuals $M' = N!$ is composed of more than 3 and a half millions of elements.

[11]By sufficiently large number of times we mean until the distribution of the realized levels of likelihoods stabilizes.

iii. At this point we verify if the likelihood obtained with a break in (i_1) and with the initial ordering is greater than a certain percentage[12] of the likelihoods obtained with random orderings.

iv. We finally reject the null of one group in favor of the alternative of two groups if the condition sub iii. is satisfied.

If we reject the null of homogeneity against the alternative of two groups we move on testing for the existence of three groups.

i. Keeping the same ordering m and fixing the first optimal splitting point obtained above (i_1) we search for a second splitting point by evaluating the likelihood at all the other possible positions[13] and we select as candidate break point (i_2) the splitting point that attain the maximum level of the likelihood.

ii. Given that we have already "accepted" the existence of a splitting point we randomly permute the subgroup that lies on the left of the first splitting point and the subgroup the lies on its right. Note that these permutations never mix up observations that lie in two different subgroups (i.e. firms that, for example, have sales smaller than the first splitting point will never be above any of those that have sales grater than the first splitting point). Again we repeat this exercise a sufficiently large number of times and, for each permutation, we store the likelihood attained when we split the sample at (i_1 and i_2) and we compute the percentiles of this distribution.

iii. We finally verify if the likelihood obtained at i_1 and i_2 with the initial ordering (m) is greater than the z per cent of the likelihoods obtained with random orderings and we reject the null of 2 group in favor of the alternative of three groups if this condition is satisfied.

If the null of two groups is rejected in favor of the alternative of three groups we go on with this approach until all the splitting points have been discovered.

[12]In the empirical part of the paper we adopt the threshold of 99 per cent.

[13]In the empirical exercise we fix an interval of 150 observations around the previously discovered splitting points to avoid spurious results that may emerge when the number of elements in a group is too small.

4.3 OLS Estimations

4.3.1 Specification of the Baseline Inventory Equation

In the previous sections we have described the general setup of the clustering analysis and the testing methodology. The objective of this section is to select an empirical specification for equation (4.1). Since we are interested in evaluating the impact of monetary policy innovations on inventories accumulation we start with the following general distributed lag model:

$$\frac{i_t - i_{t-1}}{i_{t-1}} = \alpha + \beta_1 \frac{i_{t-1} - i_{t-2}}{i_{t-2}} + \beta_2 \frac{s_t - s_{t-1}}{s_{t-1}} + \beta_3 \frac{s_{t-1} - s_{t-2}}{s_{t-2}} \tag{4.14}$$

where i_t is the (real) level of inventories and s_t is the (real) level of sales. We depart from a pure distributed lag model by augmenting our equation with the start of period inventory - sales ratio[14] and, being interested in testing for heterogeneous effects of monetary policy innovations, we also add a measure of the contemporaneous and lagged monetary policy innovations. A structure similar to the one adopted in this paper has been used by Kashyap et al. (1994) and by Bagliano and Sembenelli (2003). The main difference with Kashyap et al. (1994) is the fact that, being motivated by a different objective, they augmented the baseline equation with a liquidity indicator and its interaction term with "capital market access dummies". for similar reasons Bagliano and Sembenelli (2003) introduce in the baseline equation a measure of leverage and its interaction with dummies that are equal to one during periods of recession. We follow Kashyap et al. (1994) in the choice of imposing a zero coefficient on lagged percentage variation in real inventories for three reasons. First its contribution to the variance of contemporaneous change in inventories is in most of the cases quantitatively irrelevant. Second, being interested in OLS estimation over a sample of 16 years (observations) this allows us to save degrees of freedom in the estimation. Finally, given the extremely reduced temporal dimension of our sample, introducing a lagged dependent variable as a regressor is likely to induce considerable small sample bias in parameters' estimates. We therefore end up estimating the following equation:

$$\widehat{i}_t = \alpha + \beta_1 \left(\frac{i_{t-1}}{s_{t-1}} \right) + \beta_2 \widehat{s}_t + \beta_3 \widehat{s}_{t-1} + \beta_4 MPS_t + \beta_5 MPS_{t-1} + u_t \tag{4.15}$$

[14]This choice can be motivated by a target adjustment model of the sort seen in Lovell (1961) and has been adopted also by Kashyap, Lamont and Stein (1994).

where hats denote real percentage variations and MPSs are the monetary policy innovations (expressed in percentage points).

4.3.2 The Data

The principal source of the data used in the empirical analysis is the Company Accounts Data Service (CADS). This database includes very detailed balance sheet and profit and loss information on Italian non-financial firms. Data are collected by a consortium, which includes the Bank of Italy and all major Italian commercial banks, interested in pooling information about their clients. Data are available since 1982 and for a sample that is currently composed of (around) 50000 firms. A major advantage of CADS is related to the fact that data undergo an accurate process of reclassification that ensures a good degree of comparability both across firms and time. On the other side this database does not include firms that have credit lines for an amount smaller than (about) 80,000 euros, those that do not use their credit lines and those that are insolvent. This is likely to somewhat bias the average quality of the firms belonging to CADS with respect to the universe of firms. Among these 50000 firms we have selected those that satisfy both the following requirements. First, historical data for sales, inventories, total assets, employment, debt with banks and liquidity (cash plus current financial assets) are available for each of the years in the sample period (1983-1998).[15] Second firms must belong to the manufacturing sector and did not have changed sub-sector in any of the year of the sample period.[16] Data that satisfy both these criteria are available for a sample of 3921 firms. Nominal time series for each firm have been deflated using a sectoral (2 digit) output price deflator (Istat). Monetary policy shocks have been obtained taking the annual means of quarterly monetary policy innovations from a 7 variables VAR that includes industrial production, import prices, consumer prices, wages, the effective exchange rate, a monetary aggregate (M2) and the three month interest rate. Variables' selection and the identification strategy follows closely the lines suggested by Kim and Roubini (2000) and Kim (2002). The monetary policy shocks that we have obtained are very similar to those of Gaiotti (1999) and of De Arcangelis and Di Giorgio (2000). Moreover our monetary innovations show a high degree of co-movement (correlation coefficient close to 50 per cent) with the difference between the official discount

[15] We have decided to close the sample to avoid problems related with endogenous drop in and drop out from the sample.

[16] This choice is related to the necessity to exclude from our sample variations in inventory accumulation that are not related to firm business cycle nor to monetary policy but to more structural changes of the firm.

rate and the interest rate on fixed term advances that can be interpreted as a measure of the monetary policy stance in Italy.

4.3.3 Results

To obtain firm level sensitivities to monetary policy innovations we have run 3921 regressions according to the specification indicated in equation (4.15) over the sample period 1983-1998.[17] Descriptive statistics on the distribution of the estimated parameters[18] are reported in Table 4.1.

Table 4.1: Baseline equation: descriptive statistics on estimated parameters.

	$\widehat{\alpha}$	$\widehat{\beta}_1$	$\widehat{\beta}_2$	$\widehat{\beta}_3$	$\widehat{\beta}_4$	$\widehat{\beta}_5$
mean	47.53	-3.12	0.31	-0.17	-1.57	-1.78
std	51.40	6.65	1.11	0.87	19.26	20.68
1%	-23.08	-26.72	-2.46	-2.84	-62.53	-56.54
5%	-5.52	-10.49	-1.14	-1.34	-29.49	-30.08
10%	2.09	-6.93	-0.66	-0.96	-20.23	-20.48
25%	15.27	-3.41	-0.15	-0.52	-9.31	-9.55
50%	36.55	-1.54	0.31	-0.14	-1.12	-1.45
75%	67.13	-0.58	0.77	0.21	6.56	6.15
90%	104.90	-0.11	1.29	0.62	16.48	16.44
95%	135.01	0.17	1.73	0.99	25.92	25.03
99%	222.02	1.22	3.17	1.94	54.02	52.03
nobs	3852	3852	3852	3852	3852	3852

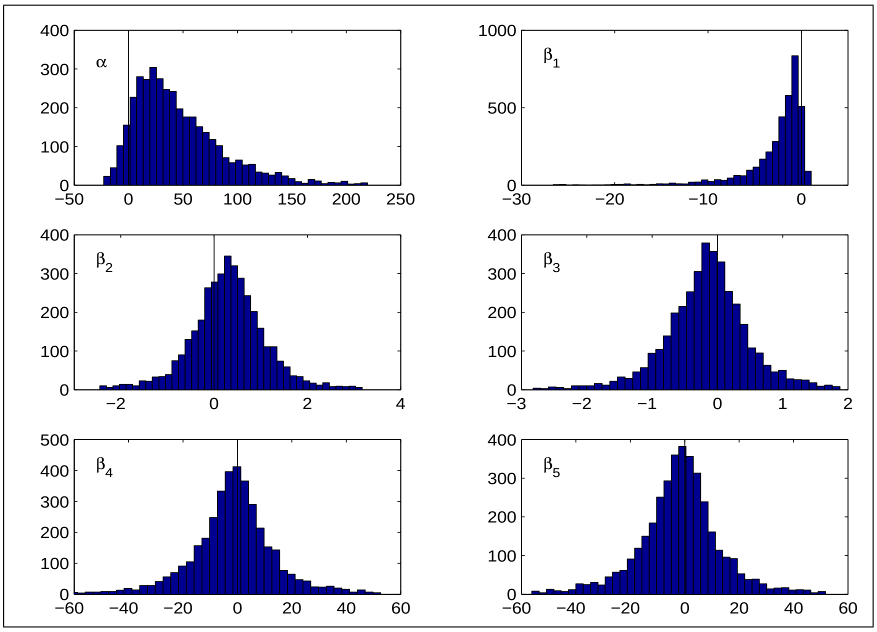
The distribution of the estimated constant term ($\hat{\alpha}$) is positioned mainly on the positive side of the real axis. This evidence, together with the estimated values for β_1, is consistent with an implicit target inventory sales ratio that assumes values between zero and 0.5. Most of the estimated coefficients on the lagged value of the actual inventory - sales ratio (β_1) are negative suggesting that the hypothesis that firms adjust inventories also to match a target inventories sales ratio is not rejected by the data. The means of the

[17] We are implicitly assuming that the structure of the errors $\boldsymbol{u}$ in equation (4.6) are such that there is no gain in efficiency in estimating (4.6) jointly. This assumption is obviously questionable and can be relaxed. However this choice has the advantage of making the first step empirical estimates simpler to obtain. Moreover, given the large cross section dimension of our sample, the possible inefficiency in these first step estimates should not affect in a substantial way our ability to properly detect clusters.

[18] Realizations of β_4 and β_5 (see equation (4.15)) that fall outside the 99.9 per cent confidence region around the sample mean have been excluded

distributions of the estimated coefficients on contemporaneous and lagged percentage variations in sales (β_2 and β_3) appears closer to zero. However it is worthwhile to note that the estimated effect of contemporaneous sales on inventories $\left(\hat{\beta}_2\right)$ shows a positive sign in around 70 per cent of the cases. The same percentage for the estimated lagged effects of the sales growth rate $\left(\hat{\beta}_2\right)$ is close to 40 per cent. Finally most of the coefficients on MPS are negative as expected. The large variance of the estimates should not surprise since during the last twenty years the variance of estimated annual monetary policy innovations is substantially smaller (the range is, more or less from -2 to 2 per cent) than the variance of inventories (that has most of the observations ranging from -40 and 70 per cent). Empirical distributions of the estimated parameters are provided in figure 4.1.

Figure 4.1: Empirical Distributions of the Estimated Parameters.



4.4 Specification of a distribution function for the clustering analysis

The final step that is necessary to make operative the theoretical structure described in section 4.2 is to select density functions for the error terms in

(4.6) and in (4.7). A standard approach is to assume, as in Canova (2004), that both error terms are drawn from a normal distribution. Under these hypothesis it can be shown that the hyper-parameters might be estimated as:

$$\widehat{\beta}_p = \frac{1}{n^p(m)} \sum_{i=1}^{n^p(m)} \beta_{i,ols} \tag{4.16}$$

$$\widehat{\Sigma}_p = \frac{1}{n^p(m)-1} \sum_{i=1}^{n^p(m)} \left(\beta_{i,ols} - \widehat{\beta}_p\right)\left(\beta_{i,ols} - \widehat{\beta}_p\right)' - \frac{1}{n^p(m)-1} \sum_{i=1}^{n^p(m)} \left(X_i X_i'\right)^{-1} \widehat{\sigma}_i^2 \tag{4.17}$$

$$\widehat{\sigma}_i^2 = \frac{1}{T-k}\left(Y_i'Y_i - Y_i'X_i\beta_{i,ols}\right) \tag{4.18}$$

This approach turned out to be not practicable because, as is often the case, most of the estimated Σ_ps were not positive definite. The alternative strategy that we have decided to follow is to assume that $\epsilon_i + (X_i'X_i)\, X_i'u_{i,p}$ in:

$$\beta_{i,ols} = \beta_p + \epsilon_i + (X_i'X_i)\, X_i'u_{i,p} \tag{4.19}$$

is distributed according to a multivariate non-centered t distribution.[19] The choice of a t distribution has many advantages with respect to the standard approach. First, as we will see in the next section, we do not incur in the problem of Σ_ps that are not positive definite. Second, since the t distribution nests the normal distribution as a special case (i.e. when the degrees of freedom go to infinity), our approach nests asymptotically (i.e. when the $(X'X)\, X'u$ term collapses to zero) that based on the normal distribution. Third, the analysis of quantile - quantile plots[20] provides evidence in favor of the hypothesis that the estimated betas come from a t distribution.

[19] Note that this is equivalent to assume that an opportune transformation of $\boldsymbol{w}$ in (4.8) follows a t distribution:

$$(X'X)^{-1} X'w = \epsilon + (X'X)\, X'u$$

[20] These plots allow to evaluate the whether an empirical distribution is significantly different from a candidate theoretical distribution. Examples are provided in figures 4.2 and 4.3. The empirical distribution is closer to the theoretical counterpart, the closer the crosses are to the dashed line. Since the implications of quantile - quantile plots are not affected by the location and the scale of the underlying random processes the variance of the normal distribution presented in the figures have been selected in such a way to have the same x-y range. The improvement in moving from the assumption of normal (figure 4.2) to a t distribution (figure 4.3) is evident.

Figure 4.2: Quantile - quantile plots: Empirical versus normal distribution.

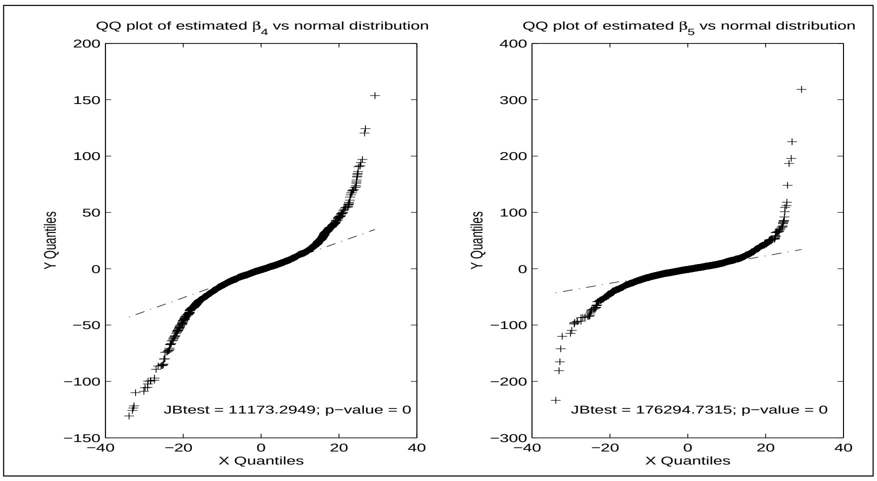
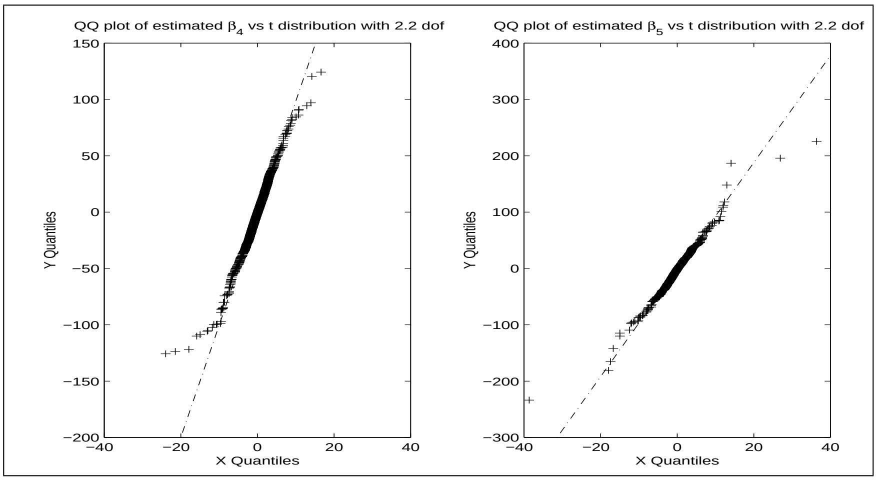


Figure 4.3: Quantile - quantile plots: Empirical versus t distribution.



4.4.1 Multivariate t Distribution

Given the evidence presented in the previous section in the empirical analysis we assume that our estimated parameters are drawn from a multivariate t distribution. In particular, since we are interested in searching for clusters with respect to the sensitivity to monetary policy shocks, we limit our analysis on the ols-estimated β_4 and β_5. We assume that $\beta_{i,I} = [\beta_{4,i,ols,I}\ \beta_{5,i,ols,I}]$, that is the vector of ols-estimated parameters of firm i that belongs to group

I, is drawn from a $StudentGen_k(\nu_I, \beta_I, \Sigma_I)$, that is we assume that $\beta_{i,I}$ has a density function defined by:

$$f(\beta_{i,I}) = \frac{\Gamma\left(\frac{\nu_I+k}{2}\right)|\Sigma_I|^{-\frac{1}{2}}}{\Gamma\left(\frac{\nu_I}{2}\right)(\nu_I\pi)^{\frac{k}{2}}}\left[1 + \frac{1}{\nu_I}(\beta_{i,I} - \beta_I)'\Sigma_I^{-1}(\beta_{i,I} - \beta_I)\right]^{-\frac{\nu_I+k}{2}} \quad (4.20)$$

where $\Gamma(.)$ is the Gamma function, $\beta_{i,I} \in R^k$ and $\nu > 0$.

4.4.2 Maximum Likelihood Estimation

Following the approach suggested by Liu and Rubin (1995) we estimate the hyper-parameters of our model (i.e. the parameters of the t distribution) iterating on first order conditions of the maximum likelihood problem. Constructing the likelihood, taking logs and equating the derivative with respect to β_I we obtain:

$$\frac{\partial \log L}{\partial \beta_I} = 0 \quad \Rightarrow \quad -\frac{1}{2}\left(\Sigma_I^{-1}\right)\sum_{i=1}^{n}\left(\frac{\nu_I + \delta_i}{\nu_I + k}\right)^{-1}(\beta_{i,I} - \beta_I) = 0 \quad (4.21)$$

$$\text{where} \quad \delta_i = (\beta_{i,I} - \beta_I)'\left(\Sigma_I^{-1}\right)(\beta_{i,I} - \beta_I) \quad (4.22)$$

and, solving for β_I, we get:

$$\beta_I = \frac{\sum_{i=1}^{n} w_i \beta_{i,I}}{\sum_{i=1}^{n(I)} w_i} \qquad \text{where} \qquad w_i = \left(\frac{\nu_I + \delta_i}{\nu_I + k}\right)^{-1} \quad (4.23)$$

note that this equation implies that the location parameters (β_I) are estimated according to a weighted least squares principle where weights are an inverse function of the mahalanobian distance δ_i of the data. In practice the implication of assuming that data comes from a t distribution is that outlaying cases (i.e. those with a large δ_i) are down-weighted, while when we assume normality observations are equally weighted (see equation (4.16)).

Defining $\Sigma_I = \Omega_I^{-1}$ and taking first order conditions of the maximum likelihood problem with respect to Ω_I we get:

$$\frac{\partial \log L}{\partial \Omega_I} = 0 \quad \Rightarrow \quad \frac{n}{2}\left(\Omega_I^{-1} - \sum_{i=1}^{n(I)}\left(\frac{\nu_I + \delta_i}{\nu_I + k}\right)^{-1}\frac{(\beta_{i,I} - \beta_I)(\beta_{i,I} - \beta_I)'}{n}\right) \quad (4.24)$$

solving for $\Omega_I^{-1} = \Sigma_I$ we get:

$$\Omega_I^{-1} = \Sigma = \frac{1}{n} \sum_{i=1}^{n(I)} w_i \left(\beta_{i,I} - \beta_I\right) \left(\beta_{i,I} - \beta_I\right)' \tag{4.25}$$

this equation implies that also the dispersion parameters are estimated according to a weighted least squares principle. Again, weights are an inverse function of the mahalanobian distance δ_i of the data.

Finally we derive the first order condition for the degree of freedom parameter:

$$\begin{aligned} \frac{\partial \log L}{\partial \nu_I} = 0 \quad \Rightarrow \quad & -\mathrm{DG}\left(\frac{\nu_I}{2}\right) + \log\left(\frac{\nu_I}{2}\right) + \sum_{i=1}^{n} \frac{(\log(w_i) - w_i)}{n} + 1 \\ & + \mathrm{DG}\left(\frac{\nu_I + k}{2}\right) - \log\left(\frac{\nu_I + k}{2}\right) = 0 \end{aligned} \tag{4.26}$$

where $\mathrm{DG}(x) = \frac{\partial \log(\Gamma(x))}{\partial x}$ is the Digamma function. Substituting $k = 2$ and exploiting the fact that $\mathrm{DG}(x+1) = \mathrm{DG}(x) + 1/x$ (Abramowitz and Stegun (1965)), equation (4.26) simplifies to:

$$\frac{\nu_I + 2}{\nu_I} - \log \frac{\nu_I + 2}{\nu_I} + \sum_{i=1}^{n} \frac{(\log(w_i) - w_i)}{n} = 0 \tag{4.27}$$

The solution for ν_I of (4.27) is:

$$\nu_I = \frac{-2}{W(-e^Z) + 1} \qquad \text{where} \qquad Z = \sum_{i=1}^{n} \frac{(\log(w_i) - w_i)}{n} \tag{4.28}$$

$W(.)$ is the LambertW function defined as the function that satisfies:

$$W(z)\, e^{W(z)} = z$$

Details on this function are available in Corless, Gonnet, Hare, Jeffrey and Knuth (1996). For the purpose of our analysis we have exploited the numerical evaluation of the Lambert W proposed by Chapeau-Blondeau and Monir (2002). Specifically, the approximation adopted in our work is:

$$\begin{aligned} &\forall z \in (-1/e, -0.33) \\ &\quad p = -\sqrt{2(e \cdot z + 1)} \\ &\quad W(z) = -1 + p - \frac{1}{3}p^2 + \frac{11}{72}p^3 - \frac{43}{540}p^4 + \frac{769}{17280}p^5 - \frac{221}{8505}p^6 \end{aligned}$$

$$\forall z \in [-0.33, -0.033]$$
$$W(z) = \frac{-8.0960 + 391.0025z - 47.4252z^2 - 4877.6330z^3 - 5532.7760z^4}{1 - 82.9423z + 433.8688z^2 + 1515.3060z^3}$$

This approach guarantees approximation errors smaller than 10e-4 for any z belonging to $(-1/e, -0.033)$ that is for any value of the degrees of freedom greater than 0.49. Following the approach suggested by Liu and Rubin (1995)[21] we find the hyper-parameters of each possible partition $\left[\beta^*_{I,4}\,\beta^*_{I,5}\,\Sigma^*_I\,\nu^*_I\right]$ iterating on first order conditions (4.23) , (4.25) and (4.28) until convergence.[22]

4.4.3 Main results

As described in section 4.2 a necessary ingredient of the clustering methodology is the selection of one or more orderings. In this paper we have selected three orderings that are closely related to the concept of "size", namely total sales, total assets and the number of employees, and three orderings that are related to the financial structure of the firm, namely the ratio between total debt and total liabilities (total leverage), the ratio between debt with banks and total liabilities (bank leverage) and the ratio between cash and current financial assets over total assets (liquidity). As is well known in this strand of literature (see for example Hubbard et al. (1995) and Bagliano and Sembenelli (2003)) pre-sample orderings are strongly suggested to avoid endogeneity problems. For this reason in the empirical analysis firms have been ordered according to nominal sales, nominal total assets and the number of employees as in 1982. As far as financial indicators are regarded, trading off the possibility of having orderings strongly affected by short term firms' financial choices and the possibility of inducing some endogeneity in our estimates we have decided to take averages of the ratios defined above over the period 1982-1984[23]. The main objective behind the selection of three orderings related to size, on top of evaluating whether the response of investment to monetary policy shocks is different for firms characterized by different dimensions, is to verify to what degree these results are influenced by the apparently innocuous choice of adopting one or the other indicator as

[21] We deviate from their approach in the fact that we have a close form solution for the degree of freedom equation while they had to find at each step the zero of equation (4.26). Our approach speeds up the estimation process in a substantial way.

[22] The algorithm has been implemented with Fortran. Robustness of the results has been checked throught Matlab's algorithms "fminsearch" and "fmincon".

[23] The fact that monetary policy was neutral during this period should substantially reduce the space for endogeneity problems

a proxy for the size of the firm. On the other side bank and total leverages are intended to verify whether sensitivity to monetary policy shocks is related to the degree of indebtedness of firm with either the banking sector or the credit sector as a whole. These indicators, as well as measures of liquidity have been often used in the literature to verify the degree of sensitivity of different classes of firms to monetary or business cycle conditions (Kashyap et al. (1994) and Caballero (1991)). In table 4.2 we present rank correlations among the orderings adopted in our work. The impression that one can get even from this very simple statistics is that even if orderings that are related to "size" are characterized by relatively high correlations, these are no so high to make the cluster analysis according to these three different orders a useless replica of the same exercise. The same is true for the correlation between total leverage and bank leverage. Interestingly rank correlations between liquidity and total leverage (equal to -0.27) and between liquidity and bank leverage (equal to -0.40) seem to suggest that that firms that are less indebted have a relatively higher amount of liquidity. This evidence is consistent with an economy where firms that do not have access to credit need to keep larger amounts of liquidity as a safeguard against unexpected shocks.

Table 4.2: Spearman (rank) correlations among orderings.

Variable	Sales	Employment	Assets	Bank debt	Total debt	Liquidity
Sales	1.00					
Employment	0.69	1.00				
Assets	0.88	0.75	1.00			
Bank debt[a]	0.04	-0.08	0.03	1.00		
Total debt[a]	-0.08	-0.23	-0.17	0.65	1.00	
Liquidity[b]	-0.01	0.01	-0.04	-0.40	-0.27	1.00

[a] Divided by total liabilities.
[b] Cash and current financial assets divided by total assets.

Optimal groups according to the montecarlo testing methodology

The next pages present a picture and a table for each of the analyzed orderings. The lines reported in each of the figures represent the log likelihood of the following events. Starting from the bottom of each picture the (flat) solid line positioned around the level of -31895 is the log likelihood for the null hypothesis that there are no heterogeneities[24] among the firms in our

[24]By heterogeneity we mean that groups may either be different because they are characterized by different location parameters $[\beta_{4,I}\beta_{5,I}] \neq [\beta_{4,J}\beta_{5,J}]$ (where I and J denote two

sample. The first erratic solid line (again starting from the bottom) represents the log-likelihood function for the hypothesis that there exists a break in the complete sample of firms at each of the location points indicated in the x-axis. For example, when firms are ordered according to their level of employment (figure 4.4) the hypothesis that there are no heterogeneities among firms gives rise to a log likelihood of (around) -31895 (first flat solid line starting from the bottom) while the hypothesis that there are two groups, with the 1000 small firms in the first group and the remaining 2852 large firms in the second group, has a log-likelihood of -31850 (first erratic solid line starting from the bottom, evaluated at x = 1000). According to the criteria outlined in section 4.2 we evaluate each possible splitting point and we select as a candidate "optimal" one the one that attains the maximum likelihood. In the case of the ordering related to the level of employment such a point is 1702 (it reaches a log-likelihood of around -31820). Once we have selected the "optimal" point we compare it with its 99% confidence band (this is the first dashed line starting from the bottom). If the log-likelihood reached by the candidate "optimal" point is larger than that of the 99 percentile of random permutations of orderings we reject the null hypothesis of "no heterogeneity" in favor of the alternative of (at least) "two groups" and we start searching for the next break. To do that we fix the first splitting point (1702) and we look for a break in each of the two subgroups (creating in this case three groups). Once we have found the new candidate "optimal" point we compare it with its 99% confidence band (second dashed line starting from the bottom of the picture) that has been constructed according to the criteria outlined in section 4.2. We go on with this mechanism until all groups have been discovered. Note that once a break point has been selected as "optimal" we do not allow for any possible break point in a (-150,150) interval around it. This choice is principally due to the fact that when groups are too small spurious results may emerge. In the tables we present, for each of the optimal groups and for the complete sample, the estimated hyper-parameters, the dimension of the groups and the thresholds in terms of sales, total assets, employment, total leverage, bank leverage and liquidity that make one firm belonging to one or the other group. Standard errors have been computed using the inverse of the information matrix computed as described in the appendix.

different groups) and/or because they are characterized by different dispersion parameters $[\Sigma_I \nu_I] \neq [\Sigma_J \nu_J]$.

Ordering: Employment

Figure 4.4: Ordering: Number of employees in 1983. Log-likelihoods.

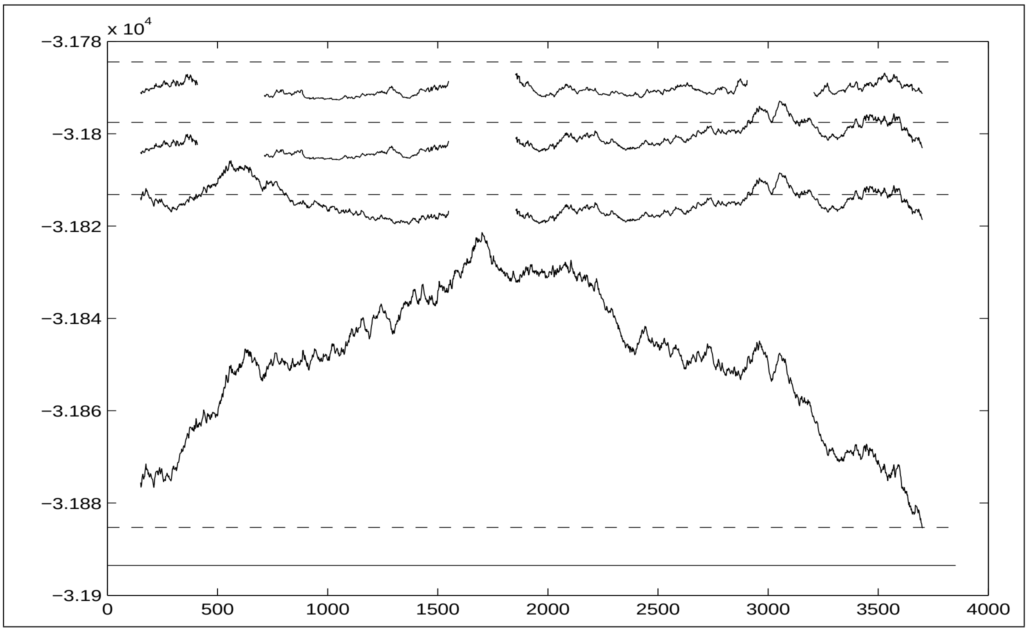


Table 4.3: Optimal groups: basic statistics. Ordering: Employment.

group	thresholds[a]	β_4	β_5	σ_1^2	$\sigma_{1,2}$	σ_2^2	ν
1	1 - 561	-1.999	-1.081	168.797	40.619	171.283	2.136
	1 - 23	(0.627)	(0.606)	(14.497)	(5.935)	(14.751)	(0.188)
2	562 - 1701	-0.254	-1.305	142.242	54.640	132.900	2.426
	23 - 52	(0.362)	(0.389)	(8.453)	(5.599)	(9.005)	(0.150)
3	1702 - 3056	-1.152	-1.857	93.448	26.204	90.458	2.621
	52 - 148	(0.324)	(0.299)	(4.851)	(3.145)	(5.765)	(0.059)
4	3057 - 3852	-1.062	-1.116	62.283	20.022	74.136	2.690
	148 - 98169	(0.359)	(0.389)	(5.427)	(3.690)	(6.136)	(0.238)
Full sample	1 - 3852	-0.974	-1.449	103.028	32.297	102.979	2.329
		(0.127)	(0.179)	(3.332)	(2.033)	(3.281)	(0.076)

Note: Standard errors in parenthesis.
[a] Numbers in normal case denote thresholds of the group in terms of rank (those with less employees rank first). Numbers in italic denote the thresholds in term of number of employees.

Ordering: Sales

Figure 4.5: Ordering: Nominal sales in 1983. Log-likelihoods.

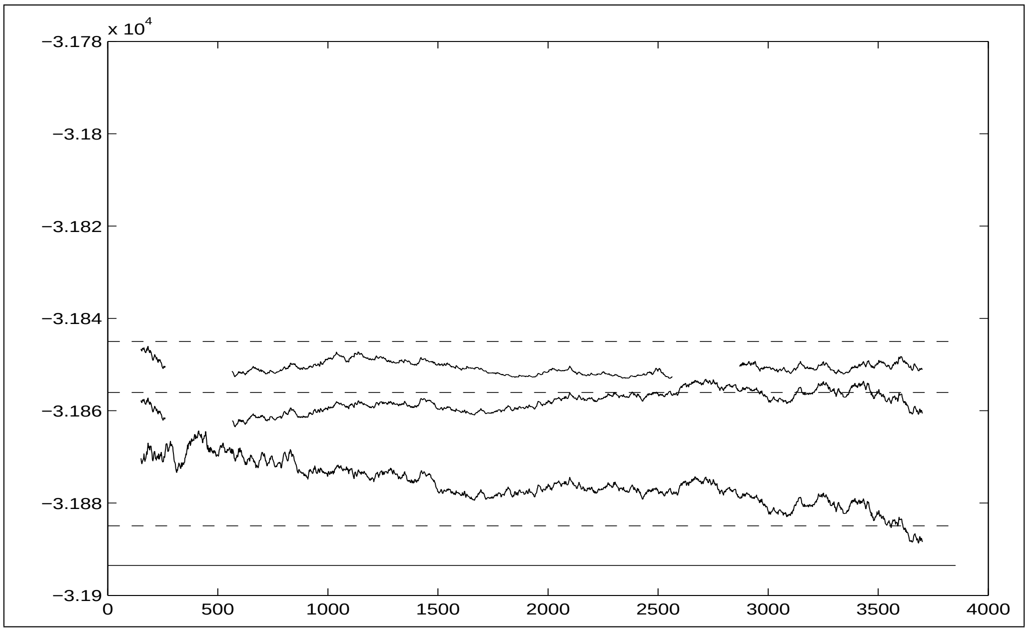


Table 4.4: Optimal groups: basic statistics. Ordering: Sales.

groups	thresholds[a]	β_4	β_5	σ_1^2	$\sigma_{1,2}$	σ_2^2	ν
1	1 - 413	-0.742	-1.201	192.074	64.451	197.097	2.635
	0 - 1.4	(0.774)	(0.813)	(20.987)	(12.186)	(20.435)	(0.301)
2	414 - 2717	-0.822	-1.533	105.879	34.177	106.892	2.416
	1.4 - 6.3	(0.259)	(0.259)	(4.772)	(2.872)	(4.864)	(0.106)
3	2718 - 3852	-1.336	-1.340	79.803	22.666	77.174	2.230
	6.3 - 5030.8	(0.338)	(0.329)	(5.521)	(3.118)	(5.314)	(0.155)
Full sample	1 - 3852	-0.974	-1.449	103.028	32.297	102.979	2.329
		(0.191)	(0.204)	(3.643)	(2.323)	(3.980)	(0.084)

Note: Standard errors in parenthesis.
[a] Numbers in normal case denote thresholds of the group in terms of rank (those with less sales rank first). Numbers in italic denote the thresholds in term of sales (millions of euro).

Ordering: Total Assets

Figure 4.6: Ordering: Total assets in 1983. Log-likelihoods.

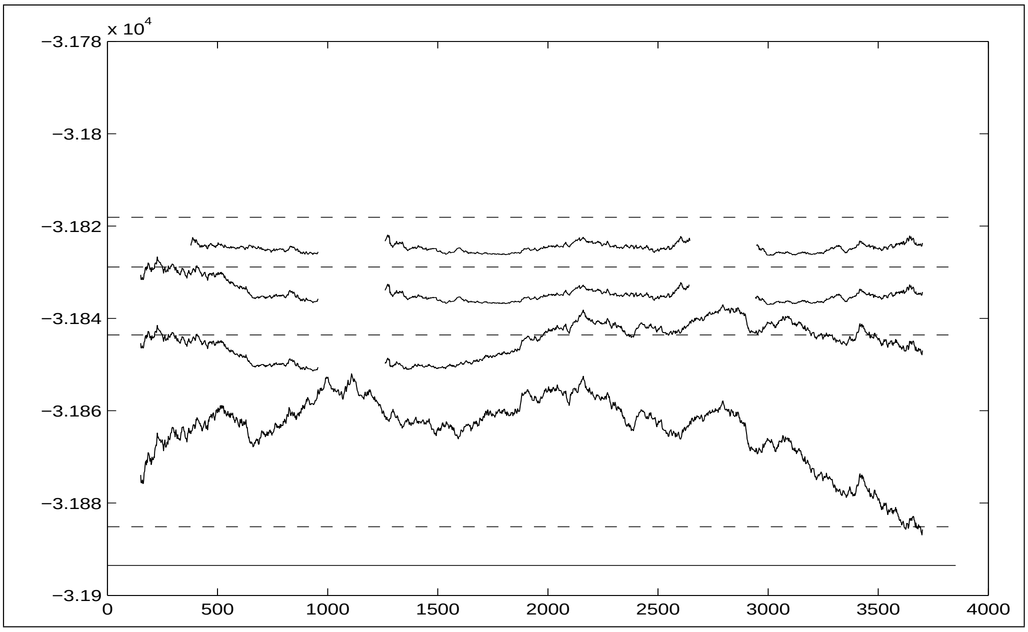


Table 4.5: Optimal groups: basic statistics. Ordering: Total assets.

groups	thresholds[a]	β_4	β_5	σ_1^2	$\sigma_{1,2}$	σ_2^2	ν
1	1 - 227	-3.354	-2.752	225.427	76.324	233.377	2.468
	0 - 0.9	(1.071)	(1.028)	(32.370)	(20.552)	(32.009)	(0.346)
2	228 - 1109	-0.875	-1.119	139.270	39.355	132.119	2.370
	0.9 - 1.8	(0.453)	(0.421)	(10.461)	(5.492)	(10.426)	(0.160)
3	1110 - 2796	-0.817	-1.576	104.228	33.623	103.983	2.483
	1.8 - 5.3	(0.300)	(0.301)	(5.588)	(3.352)	(5.647)	(0.133)
4	2797 - 3852	-1.071	-1.263	70.822	22.744	74.215	2.392
	5.3 - 3711.2	(0.338)	(0.332)	(5.152)	(3.158)	(5.401)	(0.166)
Full sample	1 - 3852	-0.974	-1.449	103.028	32.297	102.979	2.329
		(0.200)	(0.184)	(3.760)	(2.348)	(3.900)	(0.084)

Note: Standard errors in parenthesis.

[a] Numbers in normal case denote thresholds of the group in terms of rank (those with less total assets rank first). Numbers in italic denote the thresholds in term of total assets (millions of euro).

Ordering: Leverage with banks

Figure 4.7: Ordering: Leverage with banks. Log-likelihoods.

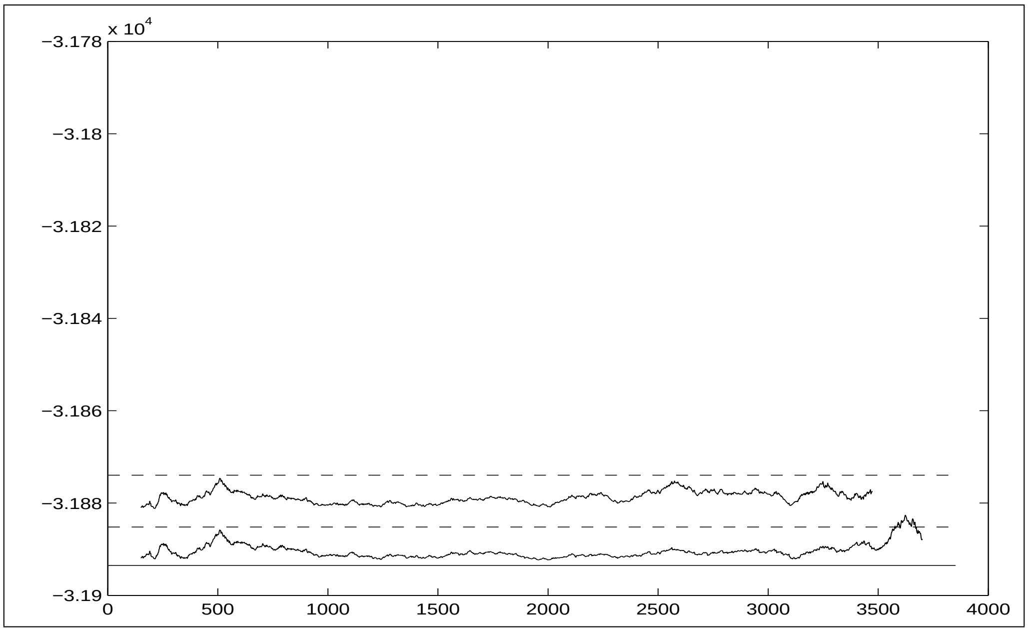


Table 4.6: Optimal groups: basic statistics. Ordering: Leverage with banks.

groups	thresholds[a]	β_4	β_5	σ_1^2	$\sigma_{1,2}$	σ_2^2	ν
1	1 - 3624	-1.005	-1.547	99.968	31.078	100.709	2.340
	0 - 0.42	(0.220)	(0.206)	(3.970)	(2.295)	(3.918)	(0.085)
2	3625 - 3852	-0.139	0.484	170.059	58.199	152.438	2.372
	0.42 - 0.69	(0.865)	(0.845)	(23.496)	(12.338)	(20.396)	(0.262)
Full sample	1 - 3852	-0.974	-1.449	103.027	32.296	102.978	2.329
		(0.209)	(0.209)	(3.566)	(2.142)	(3.677)	(0.084)

Note: Standard errors in parenthesis.

[a] Numbers in normal case denote thresholds of the group in terms of rank (those less leveraged rank first). Numbers in italic denote the thresholds in term of leverage.

Ordering: Total leverage

Figure 4.8: Ordering: Total leverage. Log-likelihoods.

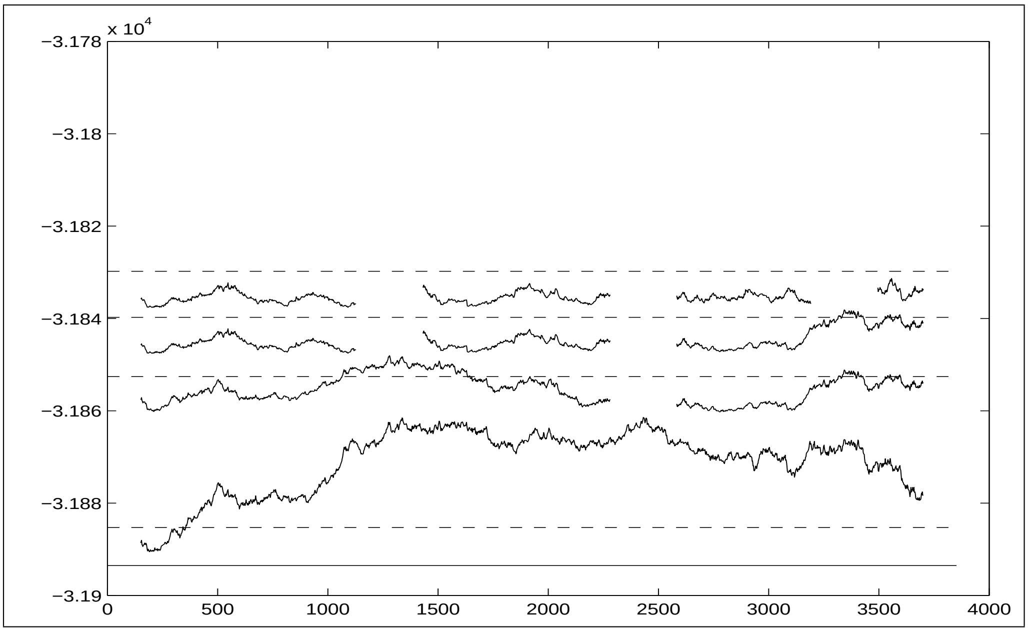


Table 4.7: Optimal groups: basic statistics. Ordering: Total leverage.

groups	thresholds[a]	β_4	β_5	σ_1^2	$\sigma_{1,2}$	σ_2^2	ν
1	1 - 1279	-0.461	-0.793	81.828	26.250	77.424	2.384
	0 - 0.60	(0.317)	(0.327)	(5.348)	(3.174)	(4.944)	(0.138)
2	1280 - 2432	-0.731	-1.590	98.928	23.286	105.561	2.460
	0.60 - 0.70	(0.356)	(0.376)	(6.355)	(3.646)	(6.968)	(0.156)
3	2433 - 3343	-2.090	-2.109	113.398	40.630	119.772	2.320
	0.70 - 0.79	(0.392)	(0.400)	(8.470)	(4.884)	(8.450)	(0.150)
4	3344 - 3852	-1.154	-1.908	182.628	65.105	169.093	2.466
	0.79 - 1.0	(0.600)	(0.611)	(15.371)	(9.416)	(14.647)	(0.235)
Full sample	1 - 3852	-0.974	-1.449	103.028	32.297	102.979	2.329
		(0.197)	(0.194)	(3.754)	(2.246)	(3.844)	(0.083)

Note: Standard errors in parenthesis.
[a] Numbers in normal case denote thresholds of the group in terms of rank (those less leveraged rank first). Numbers in italic denote the thresholds in term of leverage.

Ordering: Liquidity

Figure 4.9: Ordering: Cash and current assets divided by total assets. Log-likelihoods.

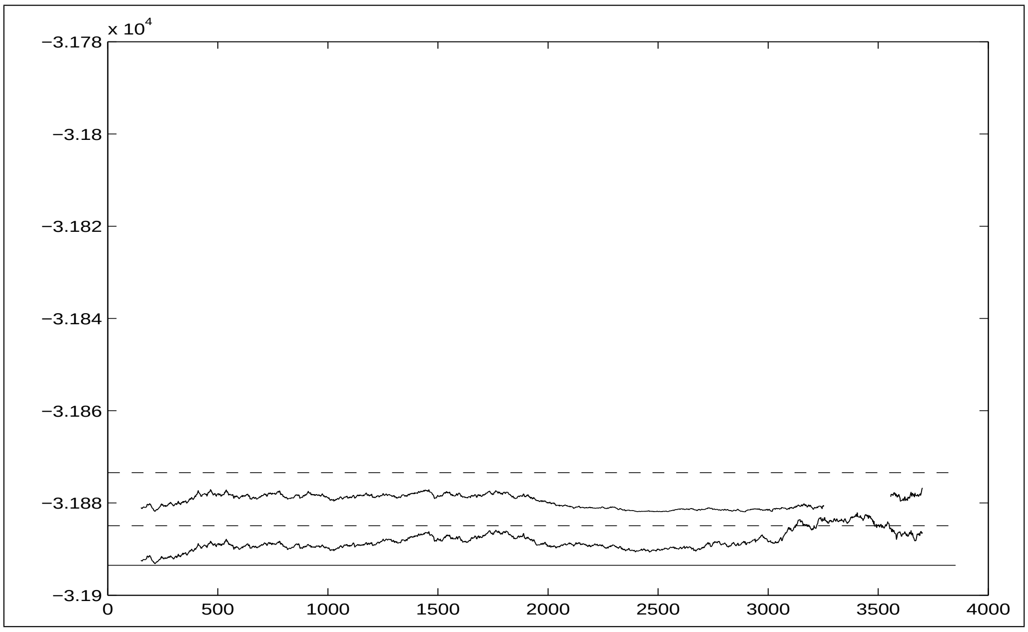


Table 4.8: Optimal groups: basic statistics. Ordering: Liquidity.

groups	thresholds[a]	β_4	β_5	σ_1^2	$\sigma_{1,2}$	σ_2^2	ν
1	1 - 3405	-0.782	-1.302	102.894	30.949	100.048	2.388
	0 - 0.15	(0.215)	(0.223)	(4.181)	(2.403)	(4.011)	(0.093)
2	3406 - 3852	-2.525	-2.732	105.478	42.580	128.636	2.030
	0.15 - 0.67	(0.596)	(0.689)	(11.945)	(7.372)	(13.513)	(0.190)
Full sample	1 - 3852	-0.974	-1.449	103.028	32.297	102.979	2.329
		(0.195)	(0.211)	(3.702)	(2.292)	(3.664)	(0.084)

Note: Standard errors in parenthesis.
[a] Numbers in normal case denote thresholds of the group in terms of rank (those with less liquidity rank first). Numbers in italic denote the thresholds in term of relative availability of liquidity.

Four groups are detected when we order firms according to their employment level with thresholds respectively equal to 23, 52 and 148 employees. Groups appear to be mainly characterized by their dispersion parameters (Σ and ν) with groups composed by "smaller" firms characterized by a larger degree of heterogeneity[25] but some differences emerge also with respect to the average effects (β). Consistently with most of the results presented in the literature, very small firms (those with a number of employees smaller than 23) show the strongest contemporaneous sensitivity to monetary policy shocks and also the largest total effect (sum of the contemporaneous and lagged effects of monetary policy on inventory investment). One more striking feature of the estimated parameters is the fact that they don't show monotonicity between size and average effect. In particular medium sized firms (number of employees between 23 and 52) and not the largest ones show the least contemporaneous and total sensitivity to monetary policy innovations. Note by incidence that if we would have adopted the 25th percentile threshold as in Gertler and Gilchrist (1994) (cut point around 1000) we would have not been able to detect any difference between the contemporaneous effect of monetary policy on small and large firms.

Three groups are detected when firms are ordered according to sales level with thresholds respectively equal to 1,4 and 6,3 millions of euros. Once more groups appear to be mainly characterized by their dispersion parameters (Σ and ν). Estimated average effects do not point to substantial differences between smaller and larger firms.

Four groups are detected when we order firms according to total assets with thresholds respectively equal to 0,8 , 1,8 and 5,2 millions of euros. As it was the case with the two previous orderings also in this case groups appear to be mainly characterized by their dispersion parameters (Σ and ν) with groups composed by "smaller" firms characterized by a larger degree of heterogeneity and very small firms (those with less than 0,8 millions of euros of total assets) show the strongest contemporaneous and total sensitivity to monetary policy shocks. However the "reduced" dimension of the group of very small firms suggests to take this last result with some care. Similar considerations hold when we analyze the results obtained ordering firms according to their leverage with banks.

Four groups are detected when firms are ordered according to total leverage with thresholds respectively equal to 0.6, 0.7 and 0.79. The estimated parameters suggest that both the contemporaneous and the lagged sensitivities of inventory investment to monetary policy shocks are strongly increasing

[25]The ν parameter is a measure of the fatness of the tails of the distribution. The smaller is ν the fatter the tails.

with respect to leverage. This result is in line with the part of the literature that has found that high leveraged firms are the most sensitive to monetary policy and business cycle conditions (for the Italian case see for example Bagliano and Sembenelli (2003)).

Two groups are discovered when firms are ordered according to their level of liquidity (cash and current financial assets divided by total assets). The estimated parameters suggest that most liquid firms are more sensitive to monetary policy shocks. This result can be rationalized assuming that firms that knows to be more exposed to credit restrictions in case of adverse monetary policy shocks are also those that hold larger amounts of liquidity.

Optimal groups according to posterior odds ratios

The results presented so far are confirmed by an analysis based on the posterior odds ratios described in section 4.2. In particular after verifying that, for $Q = 5$, the posterior odds ratio described in equation (4.12) is greater than the threshold level $e^{0.5\log(N)}$ for each of the ordering analyzed in the previous section we have moved to the sequential testing based on equation (4.12). The results are presented in tables 4.9 to 4.14. The first row of each table reports in the second and in the third columns the maximum (L^+) and the average $\left(L^{A_q}\right)$ values attained by the log-likelihood under the hypothesis of homogeneity among firms. These two values clearly coincide and are the same across orderings. In the second and third columns of the second row we present the maximum and the average values attained by the log-likelihood under the hypothesis that there are two groups. In this case the maximum is obviously larger than the average. In the fourth column we report the difference between $\log\left(L^{A_q}\right)$ and $\log\left(L^+_{q-1}\right)$. This difference, according to equation (4.13), has to be compared with $0.5\log(N)$ where $N = 3852$. If $\log\left(L^{A_q}\right) - \log\left(L^+_{q-1}\right) > 0.5\log(N) = 4.1282$ we reject the null of homogeneity and we go on testing for the existence of three groups against the null of two groups. The optimal number of groups suggested by this testing methodology is denoted with a star in the first column. To facilitate comparison we denote with a dagger the optimal number of groups suggested by the montecarlo methodology. Given that the selection criteria for the optimal splitting point is common across the two methodologies (i.e. both select as optimal breaking point the one that maximizes data predictive density) whenever the two testing strategies suggest the same optimal number of groups they also, implicitly, recommend the same location for the splitting points.

The results presented in the tables show a significant degree of homogeneity with those presented in the previous section: in half of the cases both the testing strategies suggest exactly the same number of groups and in the remaining cases the difference in the number of groups is always equal to one. Moreover is worth mentioning that in all the cases in which the two tests did not converge to the same result, the difference is always due to the presence of an extra group with a very limited number of observations. As already suggested in previous section groups with this characteristic have to be evaluated with some care.

Table 4.9: Optimal groups according to P.O. ratios. Ordering: Employment.

groups(q)[a]	$\log(L^{+}(Y\vert H_q, m))$	$\log\left(L^{A_q}(Y\vert H_q, m)\right)$	PO Statistic[b]	Threshold
1	-31893.51	-31893.51	-	-
2	-31821.39	-31848.90	44.61	4.1282
3	-31805.84	-31815.04	6.35	4.1282
†4*	-31792.86	-31801.31	4.53	4.1282
5	-31786.85	-31790.58	2.28	4.1282

Notes: [a] A star denotes the optimal number of groups according to Posterior Odds ratios. A dagger the optimal number of groups according to the montecarlo methodology. [b] The PO statistic is defined as $\log\left(L^{A_q}(Y\vert H_q, m)\right)$ - $\log(L^{+}(Y\vert H_{q-1}, m))$.

Table 4.10: Optimal groups according to P.O. ratios. Ordering: Sales.

groups(q)[a]	$\log(L^{+}(Y\vert H_q, m))$	$\log\left(L^{A_q}(Y\vert H_q, m)\right)$	PO Statistic[b]	Threshold
1	-31893.51	-31893.51	-	-
2	-31864.37	-31876.01	17.5	4.1282
†3*	-31853.19	-31857.96	6.41	4.1282
4	-31846.06	-31850.66	2.53	4.1282

Notes: [a] A star denotes the optimal number of groups according to Posterior Odds ratios. [b] The PO statistic is defined as $\log\left(L^{A_q}(Y\vert H_q, m)\right)$ - $\log(L^{+}(Y\vert H_{q-1}, m))$.

Table 4.11: Optimal groups according to P.O. ratios. Ordering: Total assets.

groups(q)[a]	$\log(L^{+}(Y\|H_q,m))$	$\log(L^{A_q}(Y\|H_q,m))$	PO Statistic[b]	Threshold
1	-31893.51	-31893.51	-	-
2	-31851.99	-31864.13	29.38	4.1282
3*	-31837.04	-31844.88	7.11	4.1282
†4	-31826.56	-31834.44	2.6	4.1282
5	-31821.79	-31824.79	1.77	4.1282

Notes: [a] A star denotes the optimal number of groups according to Posterior Odds ratios. [b] The PO statistic is defined as $\log(L^{A_q}(Y|H_q,m))$ - $\log(L^{+}(Y|H_{q-1},m))$.

Table 4.12: Optimal groups according to P.O. ratios. Ordering: Leverage with banks.

groups(q)[a]	$\log(L^{+}(Y\|H_q,m))$	$\log(L^{A_q}(Y\|H_q,m))$	PO Statistic[b]	Threshold
1*	-31893.51	-31893.51	-	-
†2	-31882.50	-31890.45	3.06	4.1282
3	-31874.58	-31878.81	3.69	4.1282

Notes: [a] A star denotes the optimal number of groups according to Posterior Odds ratios. [b] The PO statistic is defined as $\log(L^{A_q}(Y|H_q,m))$ - $\log(L^{+}(Y|H_{q-1},m))$.

Table 4.13: Optimal groups according to P.O. ratios. Ordering: Total leverage.

groups(q)[a]	$\log(L^{+}(Y\|H_q,m))$	$\log(L^{A_q}(Y\|H_q,m))$	PO Statistic[b]	Threshold
1	-31893.51	-31893.51	-	-
2	-31861.10	-31870.97	22.54	4.1282
3*	-31848.06	-31855.26	5.84	4.1282
†4	-31838.13	-31844.76	3.30	4.1282

Notes: [a] A star denotes the optimal number of groups according to Posterior Odds ratios. [b] The PO statistic is defined as $\log(L^{A_q}(Y|H_q,m))$ - $\log(L^{+}(Y|H_{q-1},m))$.

Table 4.14: Optimal groups according to P.O. ratios. Ordering: Liquidity.

groups(q)[a]	$\log(L^{+}(Y\|H_q,m))$	$\log(L^{A_q}(Y\|H_q,m))$	PO Statistic[b]	Threshold
1	-31893.51	-31893.51	-	-
†2*	-31882.13	-31888.28	5.23	4.1282
3	-31876.73	-31879.64	2.49	4.1282

Notes: [a] A star denotes the optimal number of groups according to Posterior Odds ratios. [b] The PO statistic is defined as $\log(L^{A_q}(Y|H_q,m))$ - $\log(L^{+}(Y|H_{q-1},m))$.

General assessment of the results

In summary the main results that emerge from the results presented in the previous pages are the following. First heterogeneities emerge according to most of the criteria we have selected. In particular the analysis of the dispersion parameters (variances, covariances and degrees of freedom) suggest that these heterogeneities seem to be more related to different degrees of dispersion of the elements of different clusters than to different average effects. Among the "size" orderings the one related to employment seems to have the largest information content (i.e. it reaches the maximum level of log-likelihood). Moreover the analysis of the average levels suggests that there should exists some form of nonlinearity in the effect of monetary policy shocks on inventory investment when firms are ordered according to their level of employment. This result is particularly interesting because it would have not been discovered using a standard (25th percentile cut-off criteria). As far as average levels are regarded orderings linked to sales and total assets levels in 1983 do not show interesting results. In particular, when firms are ordered according to their level of total assets, the high sensitivity to monetary policy shocks of the first group of firms has to be taken with some care because of the small dimension of the group. As far as "financial" orderings are concerned the difference between total leverage and leverage with banks results particularly striking. While the latter ordering is not able to detect any group (the only one that is discovered must be taken with some care because of its size). The ordering related to total leverage appears to be particularly informative with respect to average levels especially because the estimated dispersions are relatively similar among the first three groups.

4.5 Conclusions

We have adopted a new econometric methodology based on data predictive density to verify if the distribution of individual firms' sensitivities to monetary policy gives rise to endogenous clusters. The main results are the following. First, most of the orderings give rise to a number of clusters that is larger than two. Second, the clustering methodology detects groups that are characterized more by different degrees of within-group heterogeneity in the responses of inventory investment to monetary policy innovations than by between-groups differences in average responses. Yet some interesting features emerge from the analysis of the average between-groups responses. Third orderings based on variables that are normally thought to be equivalent proxies of the "size" of the firm (turnover, total assets and level of employment) do not lead neither to the same number of groups nor to similar splitting points. Finally some of the orderings do not show the expected monotonicity between the rank and the average effect. In particular firms that have between 25 and 50 employees turn out to be less sensitive to monetary policy shocks than firms that are smaller and firms that are larger. A similar conclusion is true when total leverage is adopted as a ranking criteria.

4.6 Appendix 4.I

The asymptotic variance of the parameters estimated in the main text can be computed following the lines suggested by Lange, Little and Taylor (1989). Denoting with J the contribution of one observation to the expected information, it can be proved that J is block diagonal with the location parameters (μ) in one block and the scale components (ν and Σ)in the other and that the elements of the two blocks are equal to:

$$J_{\mu_i,\mu_j} = \frac{\nu+k}{\nu+k+2}\frac{\partial\mu'}{\partial\mu_i}\Sigma^{-1}\frac{\partial\mu'}{\partial\mu_j} \tag{4.29}$$

$$J_{\sigma_i,\sigma_j} = \frac{\nu+k}{\nu+k+2}\frac{1}{2}\mathrm{tr}\left(\Sigma^{-1}\frac{\partial\Sigma}{\partial\sigma_i}\Sigma^{-1}\frac{\partial\Sigma}{\partial\sigma_j}\right) \tag{4.30}$$

$$-\frac{1}{2\left(\nu+k+2\right)}\mathrm{tr}\left(\Sigma^{-1}\frac{\partial\Sigma}{\partial\sigma_i}\right)\mathrm{tr}\left(\Sigma^{-1}\frac{\partial\Sigma}{\partial\sigma_j}\right) \tag{4.31}$$

$$J_{\sigma_i,\nu} = -\frac{1}{\left(\nu+k+2\right)\left(\nu+k\right)}\mathrm{tr}\left(\Sigma^{-1}\frac{\partial\Sigma}{\partial\sigma_j}\right) \tag{4.32}$$

$$J_{\nu,\nu} = -\frac{1}{2}\left[\frac{1}{2}TG\left(\frac{\nu+k}{2}\right)-\frac{1}{2}TG\left(\frac{\nu}{2}\right)\right.$$
$$\left.+\frac{k}{\nu\left(\nu+k\right)}-\frac{1}{\nu+k}+\frac{\nu+2}{\nu\left(\nu+k+2\right)}\right]$$

where $\mathrm{TG}\left(x\right)=\frac{\partial^2\log(\Gamma(x))}{\partial^2 x}$ is the Trigamma function (Abramowitz and Stegun (1965)). In the empirical evaluation of $J_{v,v}$ we have exploited the fact that $k=2$ and $TG(x+1)=TG(x)-\frac{1}{x^2}$. Summing up the expressions above over observations gives the expected information matrix. As $\nu\to\infty$ one recovers the expected information matrix for the corresponding normal distribution.

Defining $\theta=\left[\begin{array}{cccccc}\mu_1 & \mu_2 & \sigma_{1,1} & \sigma_{1,2} & \sigma_{2,2} & \nu\end{array}\right]$,defining $\xi_{i,j}$ the element (i,j) of Σ^{-1}, exploiting the fact that in our case $k=2$ and summing expressions over observations the expected information matrix $I\left(\theta\right)$ can be computed as:

$$I\left(\theta\right) = \left[\begin{array}{ccc} I_{\mu,\mu} & 0 & 0 \\ 0 & I_{\sigma,\sigma} & I_{\sigma,\nu} \\ 0 & I_{\nu,\sigma} & I_{\nu,\nu}\end{array}\right] \tag{4.33}$$

where

$$I_{\mu,\mu} = n\frac{\nu+2}{\nu+4}\Sigma^{-1}=n\frac{\nu+2}{\nu+4}\left[\begin{array}{cc}\xi_{1,1} & \xi_{1,2} \\ \xi_{1,2} & \xi_{2,2}\end{array}\right] \tag{4.34}$$

$$I_{\sigma,\sigma} = n\frac{\nu+1}{2(\nu+4)}\begin{bmatrix} \xi_{1,1}^2 & \xi_{1,1}\xi_{1,2} & \frac{\xi_{1,2}(\nu+2)-\xi_{1,1}\xi_{2,2}}{\nu+1} \\ \xi_{1,1}\xi_{1,2} & \xi_{1,2}^2 & \xi_{1,2}\xi_{2,2} \\ \frac{\xi_{1,2}^2(\nu+2)-\xi_{1,1}\xi_{2,2}}{\nu+1} & \xi_{1,2}\xi_{2,2} & \xi_{2,2}^2 \end{bmatrix} \quad (4.35)$$

$$I_{\sigma,\nu} = n\frac{-1}{(\nu+2)(\nu+4)}\begin{bmatrix} \xi_{1,1} \\ \xi_{1,2} \\ \xi_{2,2} \end{bmatrix} \quad (4.36)$$

$$I_{\nu,\nu} = n\frac{8}{\nu^2(\nu+2)(\nu+4)} \quad (4.37)$$

Taking the inverse of $I(\theta)$ we obtain the asymptotic variance of $\widehat{\theta}$.

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