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Financial crises, firm-level shocks, and large downturns: Evidence from Greece

by

Stelios Giannoulakis and Plutarchos Sakellaris

Πατησίων 76, 104 34 Αθήνα. Τηλ.: 210 8203303-5 / Fax: 210 8203499
76, Patission Street, Athens 104 34, Greece.
Tel.: (+30) 210 8203303-5 / Fax: (+30) 210 8203499
E-mail: econ@aueb.gr / www.aueb.gr

Financial crises, firm-level shocks, and large downturns: Evidence from Greece

Stelios Giannoulakis* and Plutarchos Sakellaris*,†

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Abstract

How do firm-specific shocks contribute to large economic downturns associated with financial crises? Using a large and representative dataset on Greek firms covering all sectors of the economy over the period 2000-2014, we find that the contribution of firm-specific shocks to the volatility of aggregate sales growth increased substantially (about 30%) during the Greek financial crisis and dominated the contribution of macroeconomic and sectoral shocks. We also find that, throughout the sample period, inter-firm linkages are two and a half times as important as the direct effect of firm shocks in driving aggregate fluctuations. However, during the financial crisis, the Greek economy became more granular and the direct effect of firm-specific shocks had increased importance in driving aggregate volatility.

Keywords: Firm heterogeneity, financial crises, granularity, firm shocks, inter-firm linkages, networks

JEL Classification: D20, E32, F41

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* Department of Economics, Athens University of Economics and Business

† Corresponding Author: Department of Economics, Athens University of Economics and Business. Postal Address: 76 Patission Street, 10434, Athens, Greece. Email: plutarch@aueb.gr, Tel: +30 (210) 8203 353

1 Introduction

Shocks to individual firms may have an important contribution to aggregate fluctuations. Gabaix (2011) showed that this is the case if the firm size distribution is sufficiently fat-tailed. The economy then is "granular" due to the prevalence of large firms. Others have stressed the importance of inter-firm linkages in driving the link between microeconomic shocks and aggregate fluctuations. For Acemoglu et al. (2012), and Foerster et al. (2011) these interconnections are due to input-output linkages, whilst for others (e.g. Cabrales et al., 2015; Glasserman and Young, 2015) due to financial networks.

Di Giovanni et al. (2014) provide an accounting framework to decompose firm sales growth into a macroeconomic and sectoral (macro/sectoral) shock and a firm-specific shock. They show for France that the firm-specific component is more important for aggregate fluctuations than the macro/sectoral component. They also show that interlinkages explain the overwhelming majority of firm-specific volatility. Friberg and Sanctuary (2016) show that for Sweden the firm-specific and macro-sectoral components each contribute equally to aggregate sales volatility. Our aim in this study is to examine specifically the changing sources of aggregate volatility in an economy undergoing financial crisis. A key question of interest is: How do firm-specific shocks contribute to large economic downturns associated with financial crises?

Greece is an interesting laboratory for investigating the above question for several reasons. First, the Greek Depression is one of the largest economic crisis an advanced economy has ever faced, both in magnitude and duration: the financial crisis that started in 2009 led to a 25% loss of gross output by the end of 2014. Second, the banking system had to be bailed out to prevent its collapse. Third, the crisis was preceded by a period of economic boom and rapid leveraging.[1] These facts make Greece an interesting case for examining the role of firm-specific shocks in the eruption and the contagion of a financial crisis through the production and financial networks across firms.

Using a novel and large firm-level dataset representative of the entire Greek economy over the period 200-2014 and adapting the methodology formulated in di Giovanni et al. (2014), we decompose firm sales growth into a "macro-sectoral" (capturing both sectoral and aggregate shocks) and a firm-specific component. Using these components, properly weighted and aggregated, we obtain an estimate of the relative importance of firm-level idiosyncratic shocks in aggregate sales volatility, as the ratio of the standard deviation of the aggregated firm-specific shocks to the standard deviation of aggregate sales growth. We find that the firm-specific and macro-sectoral components each contributed roughly equally to aggregate sales volatility when looking at the entire period. However, there is an important difference between the boom period of 2000 to 2008 and the crisis period that followed. During the financial crisis of 2009 to 2014, the volatility of firm-specific shocks rose five times more than that of macro-sectoral shocks.

[1] See Gourinchas et al. (2017), Chodorow-Reich et al. (2019) and Giannoulakis and Sakellaris (2020) for more information.

Having sufficient evidence for the granularity of the Greek economy we go deeper and we investigate the potential role that inter-firm linkages play in this. Relying on a model based on the approach proposed by Carvalho and Gabaix (2013) and di Giovanni et al. (2014) we find that, throughout the sample period, inter-firm linkages are two and a half times as important as the direct effect of idiosyncratic shocks in driving aggregate fluctuations. We also find that during the financial crisis, the direct effect of firm-specific shocks had increased importance in driving aggregate volatility, mainly due to the differential firm exit rates by firm size.

The linkages among firms can be attributed either to production or financial networks. The explanation for the first is simple. Firms build a network with other firms in order to obtain inputs and to sell their products. A shock to a single firm could have much larger repercussions on the macroeconomy if it diminishes the output of not only this firm, but also of others that are associated with it through a network of input-output linkages (Acemoglu et al., 2012). Financial networks arise from mutual lending and borrowing relationships among firms. Therefore, a financial shock on one firm can be dispersed into the firms that are connected with that via these lending or borrowing interconnections (Cabrales et al., 2015). A second element of inter-firm financial linkages is the confidence in the credit quality of particular firms. If a firm's perceived ability to pay declines for whatever reason, then so does the market value of its liabilities. In a mark-to-market regime this reduction in value can spread to other firms that hold these liabilities among their assets (Glasserman and Young, 2015).

Our evidence comes from proprietary firm-level data obtained from ICAP Group, S.A., a private research company that collects detailed balance sheet and income statement information for SA and Ltd companies in Greece. Our dataset is ideal for studying the granular nature of financial crises because it contains detailed information on gross sales of private firms in contrast with other widespread datasets from publicly listed firms such as Compustat. The time dimension of the dataset allows us to capture fluctuations of the business cycles of the Greek economy since it covers the Greek Depression (2009-2014) and the boom period that preceded.

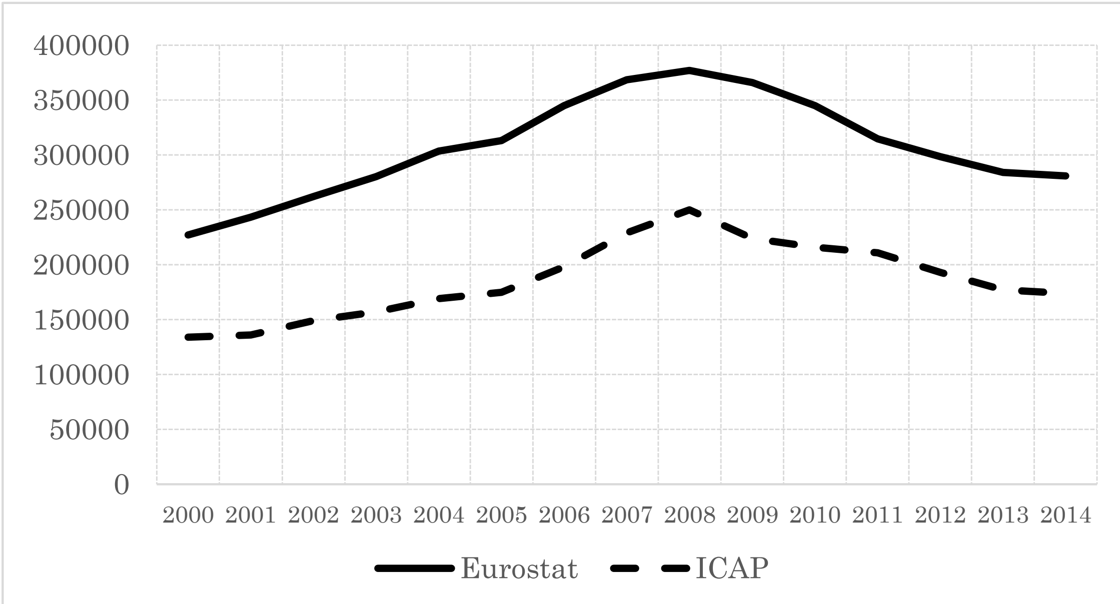
Our paper is closely related to the growing literature in finance and macroeconomics that analyzes how idiosyncratic shocks to firms propagate in the economy through inter-firm linkages. This literature focuses mainly on production and financial networks among firms or sectors. Particularly relevant empirical papers on production networks are those of Foerster et al. (2011), Acemoglu et al. (2012), Acemoglu et al. (2013), di Giovanni et al. (2014), Friberg and Sanctuary (2016), Acemoglu et al. (2016), Caliendo et al. (2018) and Popova (2019) that feature mechanisms through which input-output linkages lead to business-cycle fluctuations. Moreover, a theoretical framework for the analysis of the contribution of production networks in the aggregate fluctuations was developed by Carvalho (2008), Acemoglu et al. (2012), Acemoglu et al. (2017), Baqaee (2015) and Oberfield (2018). In particular, the aforementioned authors developed a multi-sector framework, based on the pioneering work of Long and Plosser (1983), to analyze how input-output linkages can lead to aggregate fluctuations showing that shocks hitting sectors that are highly significant as suppliers to other sectors are not average out in aggregate. The literature on financial networks is more limited. A presentation of the theoretical background of financial networks can be found in Cabrales et al. (2015), whilst an extensive literature review on this issue is provided in Glasserman and Young (2016).

There is an important and large class of theoretical models that incorporate firm-specific shocks in their analysis to explain business cycle fluctuations, but they only capture the direct effect of the these shocks and not the input-output and financial linkage effects (some recent examples are those of Bloom (2009), Bloom et al. (2018), Gilchrist et al. (2014) and Christiano et al. (2014)). Our findings indicate that for a deeper insight there is a need for theoretical models that capture production and financial networks as propagation mechanisms of idiosyncratic firm shocks. Two notable papers with general equilibrium models that incorporate the production network propagation mechanism of microeconomic shocks in the macroeconomy is that of Barrot and Sauvagnat, 2016 and Huneeus (2018), with the former to examining how idiosyncratic firm-level shocks, identified with the occurrence of natural disasters propagate across U.S. economy through firms' production networks and the later to evaluating how international trade shocks during the Great Recession propagated in Chile. Also, two interesting theoretical models that analyze the contagion, via transmission of idiosyncratic shocks to firms, in financial networks are those of Acemoglu et al. (2014) and Glasserman and Young (2015) in which the authors consider linkages among both assets and liabilities of firms, arising from mutual lending and borrowing relationships among them, via standard debt contracts.

The remainder of the paper is organized as follows. Section 2 provides a description of the data. Section 3 presents the empirical methodology we follow, while Section 4 includes the estimation results. Section 5 provides some robustness checks. Finally, Section 6 concludes.

2 Data and Descriptive Statistics

We employ a proprietary firm-level dataset obtained from ICAP Group, S.A., a private research company that collects detailed accounting information for S.A. and Limited-liability companies in Greece. All companies are legally required to publish their accounts annually and ICAP strives to cover the universe of Greek firms. ICAP data is used by commercial banks for credit decisions and by the central bank for credit rating information. Thus, the data are carefully controlled. Our dataset contains firm-level information for approximately 50,000 Greek firms operating in all sectors, except for banks and insurance companies, for the years 200 - 2014. The time dimension of the dataset allows us to capture fluctuations of the business cycles of the Greek economy since it covers the Greek Depression (2009-2014) and the boom period that preceded.To our knowledge, this paper is the first to use so large and representative a firm-level dataset for the Greek economy. A natural question that might arise here is whether our firm-level dataset resembles the aggregate Greek economy. Our sample covers roughly 60 percent of the gross output in the Greek economy over the period 2000-2014 [2].

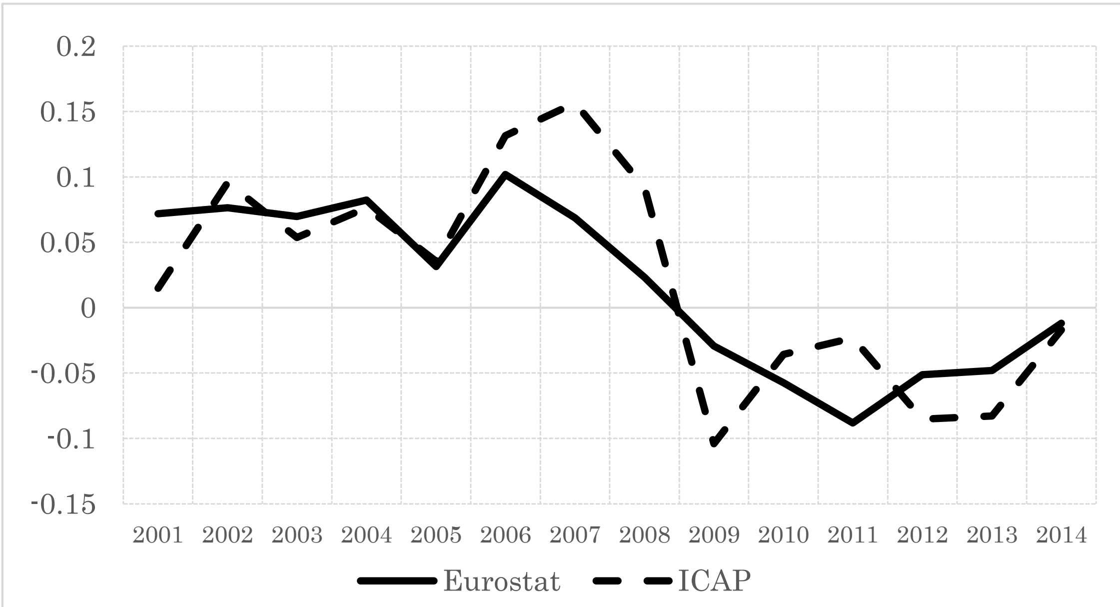


Notes: In this Figure, we compare the evolution of the aggregate gross output in our ICAP dataset with the same aggregate as recorded by Eurostat. Gross output is defined by the Bureau of Economic Analysis (BEA) as: "a measure of an industry's sales or receipts, which can include sales to final users in the economy (GDP) or sales to other industries (intermediate inputs)". At the firm-level, gross output was measured by aggregate gross sales.

Figure 1: Aggregate Gross Output in ICAP and Eurostat databases

In Figures 1 and 2 we compare the evolution of aggregate firm sales in our ICAP dataset with that of gross output as it recorded by Eurostat. We can see that the course of gross output at firm-level is very similar to that at macroeconomic level, a fact that implies that our dataset is quite representative of the Greek economy.

[2] Gross output is defined by the Bureau of Economic Analysis (BEA) as: "a measure of an industry's sales or receipts, which can include sales to final users in the economy (GDP) or sales to other industries (intermediate inputs). At firm-level, gross output is measured by aggregate gross sales.



Notes: In this Figure, we compare the evolution of the growth of total sales in ICAP dataset with the same aggregate as recorded by Eurostat. Gross output is defined by the Bureau of Economic Analysis (BEA) as: "a measure of an industry's sales or receipts, which can include sales to final users in the economy (GDP) or sales to other industries (intermediate inputs)". At firm-level, gross output was measured by aggregate gross sales.

Figure 2: Growth of Total Sales in ICAP VS Growth of Gross Output in Eurostat databases

Table 1 presents descriptive statistics for firm-level growth rates for the pre-crisis (2000-2008) and the crisis (2009-2014) periods. The average growth rate of aggregate sales, for both time periods, is lower than the (unweighted) average growth rate of individual firm-level sales in absolute terms. This is to be expected, as the unweighted metrics are dominated by small firms. Firm-level volatility increased during the crisis era. Therefore, we expect that the contribution of firm-specific shocks to aggregate fluctuations would increase. Finally, the table also reports the square root of the Herfindahl index of firm sales shares. The concentration ratio is higher for Greece than for both France (Gabaix, 2011) and Sweden (Friberg and Sanctuary, 2016), suggesting that firm-specific volatility for the Greek economy should be important. Overall the summary statistics indicate that the Greek economy is more volatile and more "granular" than both the French and the Swedish economies.

	Pre-crisis Period	Crisis Period
	2000-2008	2009-2014
Average aggregate growth rate	0.034	-0.058
Mean of individual growth rates	0.047	-0.095
Standard deviations of sales growth rate	0.593	0.639
Average $\sqrt{Herf(f)}$	0.065	0.086

Notes: This table presents the basic summary statistics for our sample. $Herf(f)$ denotes the Hirschmann–Herfindahl index of firm sales shares

Table 1: Summary Statistics

3 Methodology

To identify firm-level idiosyncratic shocks and quantify their contribution to aggregate fluctuations we adapt the methodology of di Giovanni et al. (2014).

Consider an economy with n firms. Firm's growth rate is defined as $g_{i,t} = \Delta \ln S_{i,t}$, where $S_{i,t}$ denotes the gross sales of firm i at period t, deflated by the relevant producer price index. The growth rate of a firm consists of two components: one common to all firms in the industry (i.e. a macroeconomic shock) and one specific to the firm. In other words, the firm-specific shock is the portion of the growth rate $g_{i,t}$ that is not generated by a common, industry-wide shock. Hence, the idiosyncratic shock is defined as:

$$\varepsilon_{i,t} = g_{i,t} - \delta_{j,t} \tag{1}$$

The general component $\delta_{j,t}$ can be considered as the average growth rate of sales for sector j over a period t[3].

The impact of a firm-specific shock is proportional to the size of the firm. The simplest measure of the size of a firm is its market share in the previous period, which is denoted by $s_{i,t-1} = S_{i,t-1}/S_{t-1}$, where S_{t-1} stands for the aggregate sales at period $t-1$. According to Gabaix (2011), the overall impact of firm-specific shocks on the aggregate economy constitutes the granular shock which is given by the weighted average of the firm-specific deviations from the average growth rate:

$$G_t = \sum_{i \in M} s_{i,t-1}\varepsilon_{i,t} \tag{2}$$

[3]Technically, we estimate these idiosyncratic shocks by regressing the sales growth rates on a number of sectoral dummy variables, following di Giovanni et al. (2014).

where M is the number of firms for which we calculate the granular shock. Following di Giovanni et al. (2014), we calculate the granular shock using data from all firms in the dataset independently of their size[4].

Following di Giovanni et al. (2014) , we can represent the aggregate growth rate as follows [5]:

$$g_{A,t} = \sum_{j=1}^{J} w_{j,t-1}\delta_{j,t} + \sum_{i=1}^{M} w_{i,t-1}\varepsilon_{i,t} \tag{3}$$

where $w_{j,t-1}$ is the share of sector j's sales in the total output of Greek firms, and $w_{i,t-1}$ is the share of a firm i's sales in the total output. The second term in (3) $\sum_i w_{i,t-1}\varepsilon_{i,t}$ is none other than Gabaix's (2011) "granular residual" (2). In order to ensure the compatibility of our analysis with the work of di Giovanni et al. (2014), we restrict our sample to the intensive margin of aggregate sales growth by excluding firm-year observations where a firm is an entrant or an exiter.

Let $\sigma^2_{A,t}$ be the aggregate volatility of aggregate growth rate $g_{A,t}$. We can decompose it as follows:

$$\sigma^2_{A,t} = \sigma^2_{J,t} + \sigma^2_{F,t} + COV_t \tag{4}$$

where:

$\sigma^2_{J,t} = Var\left(\sum_{j=1}^{J} w_{j,t-1}\delta_{j,t}\right)$, macro-sectoral volatility

$\sigma^2_{F,t} = Var\left(\sum_{i=1}^{M} w_{i,t-1}\varepsilon_{i,t}\right)$, firm-specific volatility

$COV_t = Cov\left(\sum_{j=1}^{J} w_{j,t-1}\delta_{j,t}, \sum_{i=1}^{M} w_{i,t-1}\varepsilon_{i,t}\right)$, covariance of the shocks from different levels of aggregation.

Specification (4) allows as to quantify the contribution of individual shocks to aggregate fluctuations. For a deeper insight into the channels through which firm-specific shocks affect aggregate volatility we further decompose idiosyncratic volatility into the contribution of individuals variances and comovements between firms (Carvalho and Gabaix, 2013; di Giovanni et al., 2014):

$$\sigma^2_{F,t} = \underbrace{\sum_{i=1}^{M} w^2_{i,t-1} Var\left(\varepsilon_{i,t}\right)}_{Direct_t} + \underbrace{\sum_{k\neq i} w_{k,t-1}w_{i,t-1} Cov\left(\varepsilon_{k,t}, \varepsilon_{i,t}\right)}_{Link_t} \tag{5}$$

[4]The definition of M varies in the literature. Gabaix (2011) restricted M to the 100 largest firms in US, implying that only large firms affect business cycles. In contrast, di Giovanni et al. (2014) estimated macroeconomic and idiosyncratic shocks using data from the universe of French firms independently of their size. Karasik et al. (2016) combined these approaches by examining two cases: the case of 10 largest Canadian companies and the case of all companies.

[5]We do not have firm exports data, so we cannot differentiate by the destination of firm sales, as di Giovanni et al. (2014) do. This should not affect the estimates much as Greece has a low exports-to-GDP ratio (23% versus 38% for the European Union over 2000-2014). In section 5.2 we provide some more arguments for robustness.

The first term in equation (5) captures the direct effect of idiosyncratic shocks to firms on aggregate volatility in the absence of inter-firm linkages. This "direct" effect should be negligible according to many macroeconomic models in which idiosyncratic shocks vanish at the aggregate level.

The second term in equation (5) designates comovements between firms' outputs, i.e. covariances of idiosyncratic shocks across firms. This correlation emerges from linkages through the input-output structure and intermediary consumption or through the supply constraints in the labor market or through financial networks across firms. In this case, shocks to one firm will affect output dynamics of other firms related with the first one. This "link" effect has been ignored by a large part of the literature in macroeconomics based on the argument that covariances between firms are repercussions of macroeconomic shocks that firms face (Acemoglu et al., 2012).

We estimate econometric specifications (3), (4) and (5)[6] following the algorithms provided by di Giovanni et al. (2014)[7].

4 Estimation Results

Table 2 presents descriptive statistics of the actual growth rates of firms' sales and its components resulting from decomposition (3). It is clear that the volatility of actual sales growth is dominated by its firm-specific component, rather than the macro-sectoral shocks. The standard deviation of the firm-specific component is almost the same as the standard deviation of actual sales growth and the correlation is almost perfect. To the contrary, the macro-sectoral component is much less volatile and has lower correlation with actual sales growth. These results lie in accordance with the widely accepted view that most shocks hitting firms are idiosyncratic (Haltiwanger, 1997). In addition, the standard deviation we find (either the actual or the firm-specific or macro-sectoral) is much larger than that of Gabaix (2011) and Friberg and Sanctuary (2016) who studied the cases of France and Sweden respectively. The reason for that is that our sample, in contrast with theirs, covers the period of the global financial crisis which for Greece was prolonged by both the sovereign debt and banking crises.

Figure 3 and Table 3 report the estimates for the aggregate volatility and its components according to equation (4). In particular, Figure 3 depicts the estimates of aggregate volatility $\sigma_{A,t}$ and its components $\sigma_{j,t}$ (firm-specific) and $\sigma_{F,t}$ (macro-sectoral) for the Greek economy during the period 2001-2014, together with two kinds of 95% confidence intervals: analytical and bootstrapped. Table 4 gives the averages of our estimates of $\sigma_{A,t}$, $\sigma_{j,t}$ and $\sigma_{F,t}$, as well as their ratios, over the whole sample period and over the pre-crisis (2000-2014) and crisis (2009-2014) period separately.

[6]We have also estimated these three specifications using fixed weights, in line with di Giovanni et al. (2014). These alternative specifications yields very similar results and are available upon request.

[7]Retrieved on December, 2019, from here.

	Obs	**Mean**	**St. Dev.**	**Correlation**
Actual	406,670	-0.017	0.653	1.000
Firm-specific	406,670	0.000	0.637	0.987
Macro-sectoral	1,377	-0.012	0.173	0.065

Notes: "Actual" refers to $g_{i,t}$, "Firm-specific" to $\varepsilon_{i,t}$, and "Macro-sectoral" to $\delta_{j,t}$ (equation (1) of main text). Column (2) reports the average $g_{i,t}$, $\varepsilon_{i,t}$, and $\delta_{j,t}$ in the sample. Column (3) reports the average sample standard deviation of $g_{i,t}$, $\varepsilon_{i,t}$, and $\delta_{j,t}$. Column (4) presents the correlation between $g_{i,t}$, $\varepsilon_{i,t}$, and $\delta_{j,t}$.

Table 2: Summary Statistics and Correlations of Actual Firm-level Growth and Firm-specific VS Sector-specific Components

	St. Dev.		
	Whole Period	Pre-crisis	Crisis
Actual	0.1176	0.1149	0.1211
Firm-specific	0.0824	0.0707	0.0980
Macro-sectoral	0.0838	0.0811	0.0875
	Relative St. Dev		
	Whole Period	Pre-crisis	Crisis
Actual	1.0000	1.0000	1.0000
Firm-specific	0.7008	0.6150	0.8094
Macro-sectoral	0.7129	0.7056	0.7222

Notes: The table displays the decomposition of aggregate volatility $\sigma_{A,t}$ of sales growth into firm-specific $\sigma_{F,t}$ and macro-sectoral $\sigma_{J,t}$ components, averaged over the period 2001-2014, the pre-crisis period 2001-2008, and the crisis period 2009-2014.

Table 3: The Impact of Firm-specific and Macro-Sectoral Shocks on Aggregate Volatility

From Table 3 we can see that macro-sectoral and firm-specific shocks contributed roughly equally to aggregate sales volatility over the entire period - roughly 70% each[8]. However, there is a marked difference between the boom and crisis periods. The financial crisis brought a substantial increase in the importance for aggregate fluctuations of firm-specific relative to macro-sectoral shocks. From Figure 3 it is apparent that although the contribution of both macro-specific and firm-specific component increased during the crisis, the contribution of the latter rose five times more than that of the former (increases of 39% and 8% respectively)[9]. Therefore, firm-specific shocks seem to contribute more than macro-sectoral shocks to downturns - or more precisely to financial crises (as the Greek Depression was).

Using equation (5), we further decompose the idiosyncratic component into two terms: the direct channel (variation in individual shocks - DIRECT) and the effect of inter-firm linkages (covariance of shocks between firms - LINK). Figure 4 depicts the estimates for the DIRECT and the LINK effects of the firm-specific component. It is apparent from the figure that the LINK component explains most of total firm-specific volatility (specifically 93% over the time period 2001-2014). Nevertheless, the DIRECT component is not inappreciable (explaining 35% over the time period 1998-2014). During the financial crisis, the Greek economy became more granular. The contribution of the direct effect of firm-specific shocks in driving aggregate volatility increased by 75%.

The preponderance of inter-firm linkages in driving aggregate fluctuations is likely due to important production and financial networks across firms. Input-output linkages propagate shocks to a single firm onto the macroeconomy through a network of interconnections (see e.g. Acemoglu et al., 2012). Financial networks arise from mutual lending and borrowing relationships among firms (see e.g. Cabrales et al., 2015) and can generate similar propagation of microeconomic shocks.

In addition, the increased importance of the direct component during the financial crisis seems to be due to differential firm exit rates by size category. Table 4 presents the exit behavior during the crisis (2009-2014) of firms that existed in 2008 (i.e. the last year before the eruption of the crisis). As we can observe exit rates during the crisis were higher for small firms. As a result the Herfindahl index of firm sales shares rose from 0.065 in the pre-crisis period to 0.081 during the crisis leading to a higher direct effect of firm-specific shocks[10]. The clear negative relationship between exit hazard and firm size accords with the results of Giannoulakis and Sakellaris (2020).

[8]These numbers add up to more than 1 because they have been converted to standard deviations and due to the existence of non-zero covariance terms.

[9]These results are robust to allowing for firm sales growth to respond heterogeneously to macroeconomic and sectoral shocks with respect to three observable firm characteristics: firm age, firm size, and various measures of financing constraints. See section 5.1 for more details

[10]This argument can be more comprehensible if we assume identical variances of firm-specific shocks across firms (di Giovanni et al., 2014), i.e. $Var(\varepsilon_{i,t}) = \sigma^2$, $\forall i \in N$. Under this assumption, the direct effect can be written as:

$$DIRECT = \sigma^2 \times \sum_{i=0}^{N} w_{i,t-1}^2 = \sigma^2 \times Herf_{t-1}$$

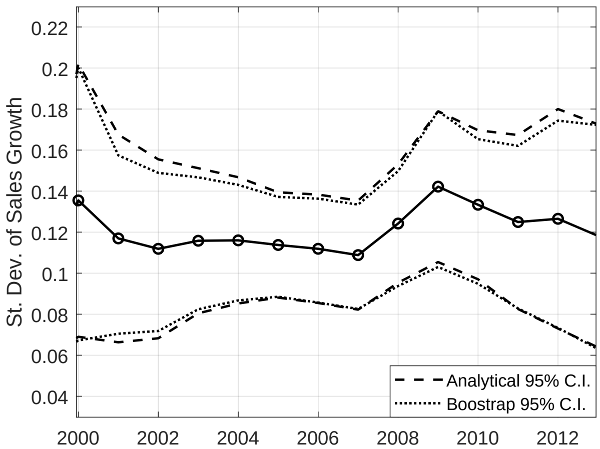
where $Herf_{t-1}$ denotes the Herfindahl index. The above expression implies that the larger is the Herfindahl index, the greater will be the direct effect of firm-specific shocks.

These authors found that the survival probability of Greek firms during the period 2001-2014 is negatively correlated with firm size.

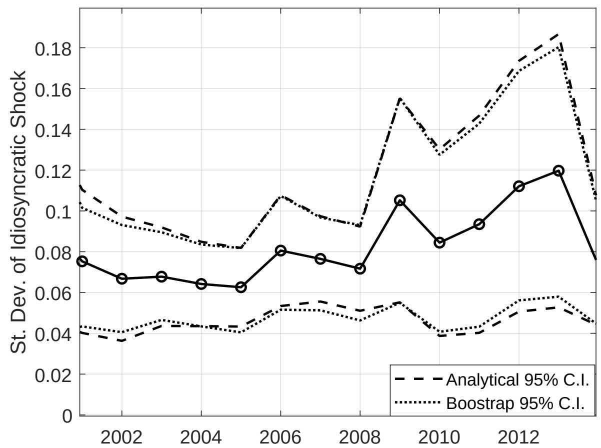
Percentiles of Sales Distribution	Firm exits during Crisis	Exits as percentage of Number of Firms
0-20	4,752	70%
21-40	3,185	47%
41-60	3,126	46%
61-80	1,966	29%
81-100	1,241	18%
Top 100 firms	0	0

Notes: In this table we analyze the exit behavior during the crisis (2009-2014) of firms that existed in 2008. We do this by size groups. We define size categories using percentiles of the 2008 sales distribution. In the third column we present the ratio of firm exits that occurred during the crisis as a share of the number of firms in 2008.

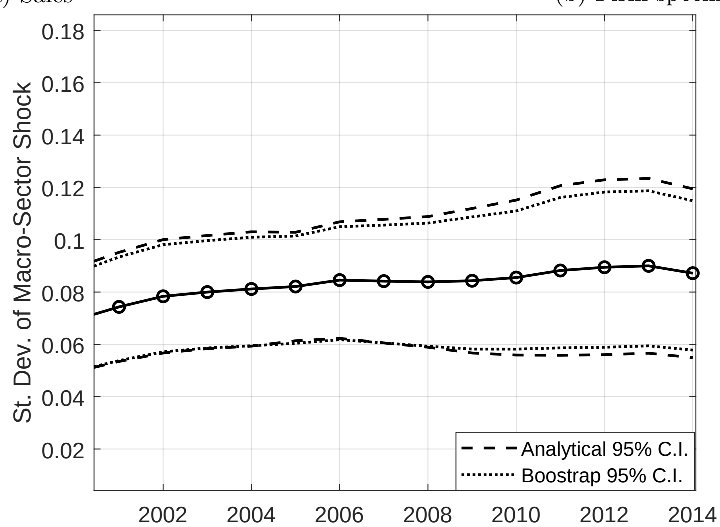
Table 4: Firm Exits by Size during the crisis



(a) Sales



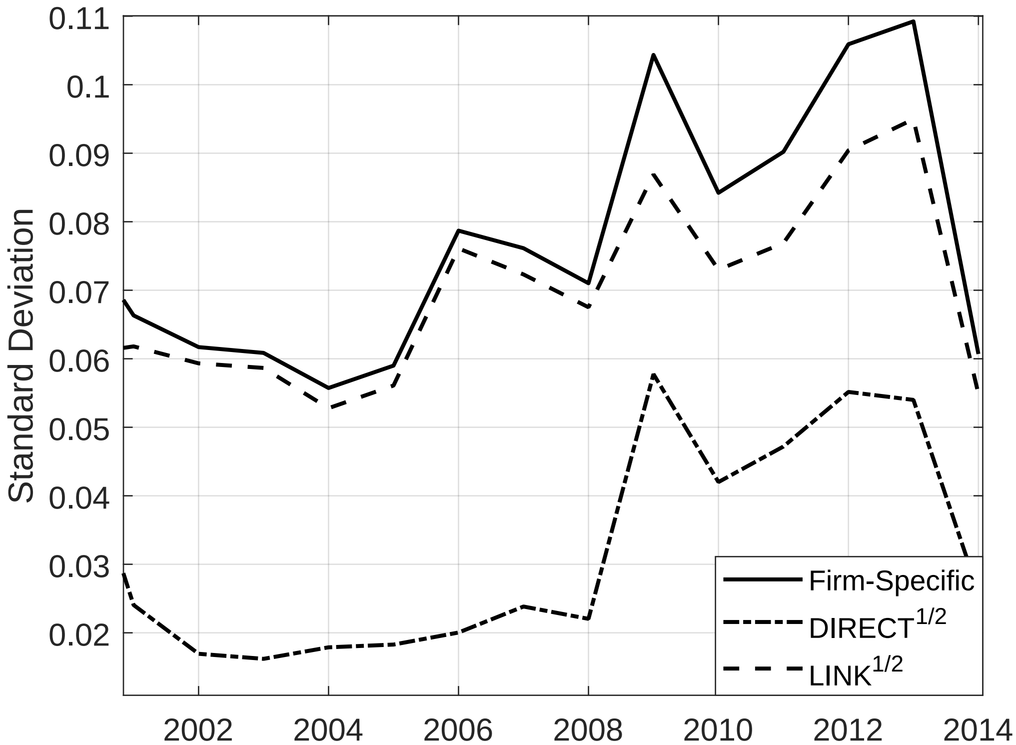
(b) Firm-specific



(c) Macro-Sectoral

Notes: This figure presents the estimates of aggregate shocks $\sigma_{A,t}$ into firm-specific $\sigma_{j,t}$ and sector-specific $\sigma_{F,t}$ components from the Greek economy over the period 2001-2014, along with both analytical and bootstrap 95% confidence intervals, according to the variance decomposition (4).

Figure 3: Volatility of sales growth and its components



Notes: This figure presents a decomposition of the firm-specific aggregate variance into two components that measure the contribution of firm-specific variances ($\sqrt{DIRECT_t}$) and of covariances across firms ($\sqrt{LINK_t}$). The decomposition is based on equation (5).

Figure 4: Contribution of individual volatilities and covariance terms to firm-specific fluctuations

5 Sensitivity Analysis

5.1 The Role of Firm-specific Factors

There is a growing literature in macroeconomics and corporate finance that documents heterogeneous responses of firms to aggregate fluctuations. This literature has attributed these heterogeneous responses of firms to various firm-specific factors such as: firm age and firm size (Fort et al. 2013; Siemer 2019), access to capital markets (Gertler and Gilchrist, 1994; Chodorow-Reich, 2014), intensity of research and development (Comín and Philippon, 2005), and export intensity (Blum et al., 2013). For Greece, Giannoulakis and Sakellaris (2020) examined the heterogeneous responses of Greek firms to the 2009 financial crisis with respect to their age, size and the financing constraints they face.

Therefore, it is quite possible that firms will react differently to sector- and macro-level shocks due to firm-specific factors. If this is the case, the estimated values of $\varepsilon_{i,t}$ from growth decomposition (3) will reflect not only idiosyncratic shocks to firms, but also the heterogeneous responses of firms to aggregate and sectoral shocks.

In order to disentangle the role of heterogeneous firm responses, due to observable firm-specific factors, from the impact of idiosyncratic firm shocks on aggregate fluctuations, we estimate the following augmented version of growth decomposition (1):

$$g_{i,t} = \delta_{j,t} + \delta_{j,t} \times SF_{i,t} + \beta SF_{i,t} + \varepsilon_{i,t} \tag{6}$$

where $SF_{i,t}$ is a particular observable firm-specific factor. This augmented econometric specification allows heterogeneity of firm responses to country- and sector-level shocks to be systematically related to observable firm characteristics, apart from idiosyncratic shocks. We use three firm characteristics that they have been widely adopted in the literature (di Giovanni et al., 2014): (i) firm age[11], (ii) firm size (sales quintile dummy), (iii) financial leverage (quintile dummy for the firm's debt-to-assets ratio[12]). We also examine the case in which all of the aforementioned firm-specific characteristics are included together[13].

The question of interest is: what is the role of firm-specific responses to macro-sectoral shocks in business cycle fluctuations? To answer this question, we re-estimate the variance decomposition (4) using equation (6).

Table 5 presents the results. Allowing firms to exhibit heterogeneous responses to macro-

[11] Following Haltiwanger et al. (2013) and Giannoulakis and Sakellaris (2020) we use a dummy variable that receives the value 1 if firms are young (less than 5 years old) and the value 0 otherwise.

[12] As an alternative measure of financial leverage we use the debt-to-sales ratio. The results are very similar and are available upon request.

[13] For the estimation of model (6), we find that firm age and size have a negative impact on firm sales growth whilst leverage has a positive one. These results are in accordance with the findings of Giannoulakis and Sakellaris (2020) who document that young and small firms exhibited higher sensitivity, in terms of sales growth, to the Greek crisis than their large and mature counterparts. They find also that a large part of this differential impact of the Greek crisis on firm growth stemmed from financing constraints that young and small firms faced.

	Whole Period		**Pre-crisis Period**		**Crisis Period**	
	St. Dev	Relative SD	St. Dev	Relative SD	St. Dev	Relative SD
Actual	0.1176	1.0000	0.1149	1.0000	0.1211	1.0000
Differing Firm Sensitivity by Age						
Firm-specific	0.0802	0.6821	0.0684	0.5956	0.0959	0.7915
Direct	0.0308	0.3650	0.0193	0.2810	0.0462	0.4770
Linkage	0.0734	0.9237	0.0656	0.9591	0.0838	0.8763
Differing Firm Sensitivity by Size						
Firm-specific	0.0864	0.7346	0.0769	0.6694	0.0990	0.8171
Direct	0.0305	0.3387	0.0189	0.2481	0.0460	0.4596
Linkage	0.0800	0.9322	0.0745	0.9675	0.0874	0.8851
Differing Firm Sensitivity by Finance (Debt-to-assets)						
Firm-specific	0.0777	0.6610	0.0660	0.5746	0.0933	0.7702
Direct	0.0305	0.3732	0.0190	0.2871	0.0459	0.4880
Linkage	0.0708	0.9197	0.0632	0.9572	0.0810	0.8698
Differing Firm Sensitivity by Age, Size and Finance						
Firm-specific	0.0794	0.6753	0.0703	0.6120	0.0915	0.7553
Direct	0.0303	0.3660	0.0191	0.2734	0.0452	0.4894
Linkage	0.0726	0.9211	0.0676	0.9604	0.0793	0.8687

Notes: This Table reports the estimated firm-specific component of aggregate volatility under the augmented model (6) in which firms are allowed to exhibit heterogeneous sensitivity to sectoral shocks according to 3 observable firm-specific characteristics: firm age, firm size and access to finance. We report these results for the whole time period 2001-2014, and the pre-crisis (2001-2008) and crisis (2009-2014) periods as well. The word "Actual" denotes the average standard deviation of actual aggregate sales growth over 2001 - 2014 which is given by $\frac{1}{T}\sum_{t=2001}^{2014}\sigma_{A,t}$. The term "Firm-specific" stands for the average standard deviation of the firm-specific component, $\frac{1}{T}\sum_{t=2001}^{2014}\sigma_{F,t}$, and its average value relative to the actual, $\frac{1}{T}\sum_{t=2001}^{2014}\frac{\sigma_{F,t}}{\sigma_{A,t}}$. The words "Direct" and "Linkage" denote the direct $\left(\sqrt{\sum_{i=1}^{M} w_{i,t-1}^2 Var\left(\varepsilon_{i,t}\right)}\right)$ and the linkage $\left(\sqrt{\sum_{k\neq i} w_{k,t-1}w_{i,t-1}Cov\left(\varepsilon_{k,t},\varepsilon_{i,t}\right)}\right)$ effect of the idiosyncratic component, respectively. "Size" is the dummy for the firm's quintile in the sales distribution. "Age" is the dummy for whether the firm is more than 5 years old. "Finance" is the quintile dummy for the firm's debt-to-assets ratio which constitutes a proxy for the financing constraints that a firm faces.

Table 5: Systematic firm heterogeneity VS firm-specific shocks

sectoral shocks according to the three aforementioned firm-specific factors has an almost imperceptible impact on the firm-specific component of aggregate volatility whether focusing on the whole sample period or on the pre-crisis and crisis periods separately. To be more precise, allowing firm sensitivity to differ by firm age or access to finance led to a very small fall of the contribution of firm-specific shocks in the aggregate volatility whilst allowing heterogeneous firm responses across firm size distribution led to a very small increase. Also we observe a tiny fall in the relative standard deviation of the idiosyncratic component in the case of the inclusion of all firm characteristics in model (6). In any case, these changes are small and cannot bring our conclusions about the role of idiosyncratic shocks in aggregate fluctuations into question. This is clear even when we examine the two effects (the "direct" and the "linkage") of the idiosyncratic component separately.

It is noteworthy that in all different versions of econometric specification (6), independently of which control we include, the contribution of idiosyncratic component to aggregate fluctuations became significantly larger during the crisis. This result reinforces our conclusion that firm-specific shocks contribute more to large economic downturns than to business cycle upturns.

In summary, our results are robust to allowing for firm sales growth to respond heterogeneously to macroeconomic and sectoral shocks according to systematic firm-specific factors. The overwhelming majority of the heterogeneous response of firms to business cycle fluctuations can be attributed to idiosyncratic shocks.

5.2 Results for the Manufacturing Sector: an exporting sector

Unlike di Giovanni et al. (2014) our dataset does not contain export data. Thus, we cannot distinguish sales shocks by destination of exports and we concentrate on decomposing total (domestic and export) firms sales into aggregate and firm-level components. To check whether this affects our results much, we study a single sector that has more exporting activity than the rest of the economy, manufacturing, and contrast it to the whole economy, that contains many non-tradeable sectors. If export-destination demand shocks are not accounted for by a macro-sector-destination component, they will show up as firm-specific shocks. Furthermore, they will show up as higher covariance terms (LINK) in the decomposition of firm-specific shock volatility to DIRECT and LINK. If export-destination demand shocks are important for Greece, we would expect to find that in manufacturing the contribution of firm-specific shocks to aggregate fluctuations is higher than it is in the whole economy. Furthermore, we would expect to find that in manufacturing the contribution of LINK to firm-specific shock volatility is higher than it is in the whole economy.

In fact we find the opposite. The contribution of both shocks to aggregate fluctuations was higher than that of idiosyncratic shocks both before and during the crisis. Despite the fact that the contribution of firm-specific shocks increased (about 23 %) after 2009, it did not dominate the contribution of macro-sectoral shocks (which also increased by 15 %).

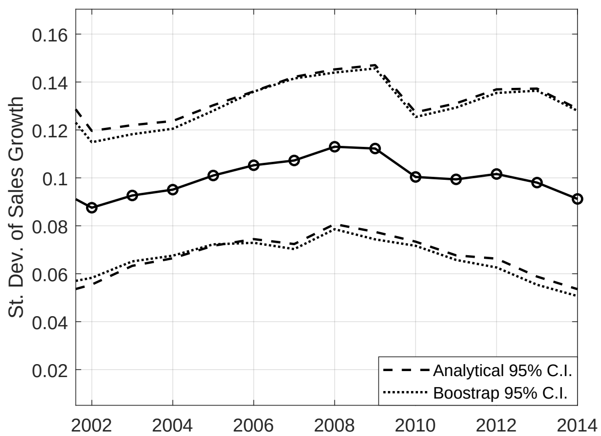
Moreover, we find that the direct component of the idiosyncratic volatility is larger in the manufacturing sector than in the entire economy, especially after the start of the Greek financial crisis.

These results, and the fact that Greece is a low-exporting economy, lead us to believe that the absence of firm export-destination data do not affect much our results.

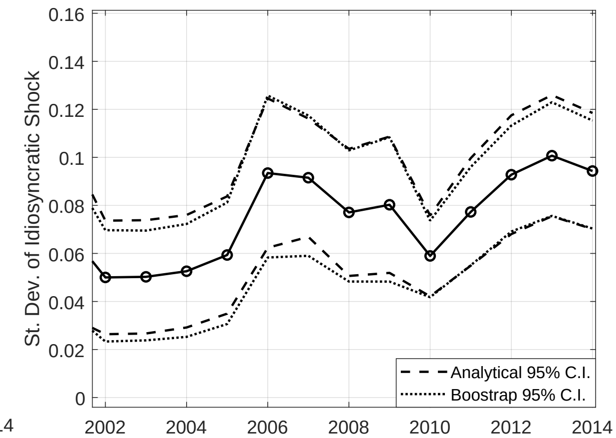
	St. Dev.		
	Whole Period	Pre-crisis	Crisis
Actual	0.1001	0.0998	0.1005
Firm-specific	0.0750	0.0682	0.0841
Macro-sectoral	0.0861	0.0807	0.0933
	Relative St. Dev		
	Whole Period	Pre-crisis	Crisis
Actual	1.0000	1.0000	1.0000
Firm-specific	0.7490	0.6830	0.8364
Macro-sectoral	0.8603	0.8086	0.9288

Notes: The rows of the table refer to the decomposition of aggregate shocks $\sigma_{A,t}$ into firm-specific $\sigma_{F,t}$ and sector-specific $\sigma_{j,t}$ components for the sector of Manufacturing, averaged over the period 2001-2014, the pre-crisis period 2001-2008 and the crisis period 2009-2014.

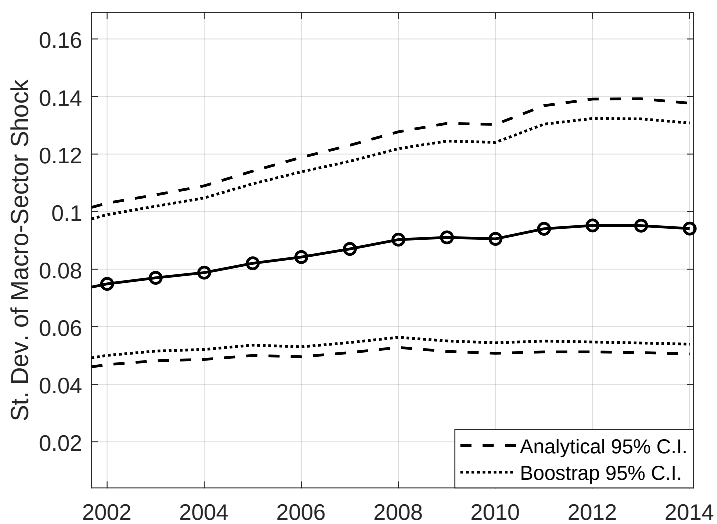
Table 6: The Aggregate Impact of Firm-specific Shocks on Aggregate Volatility in the Manufacturing Sector



(a) Sales



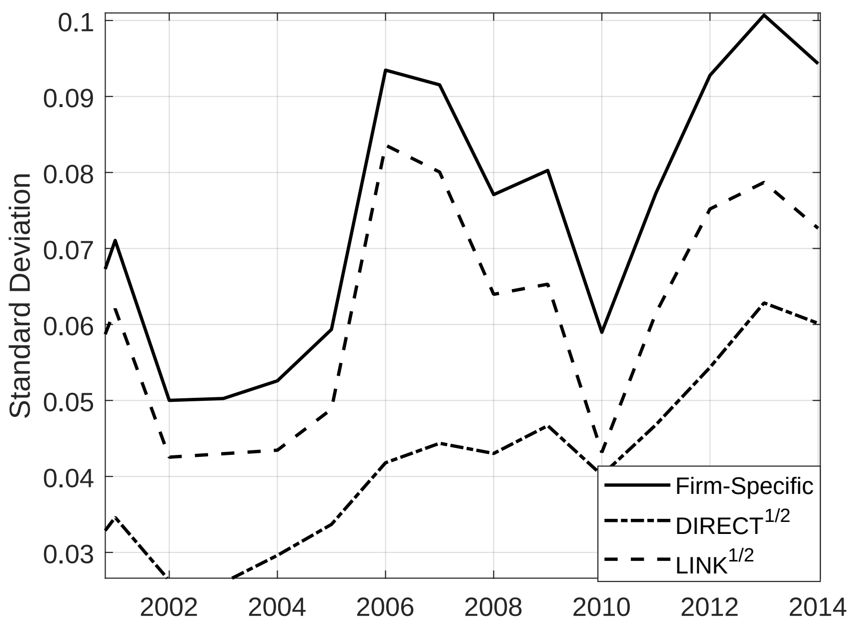
(b) Firm-specific



(c) Macro-Sectoral

Notes: This figure presents the estimates for the volatility of aggregate shocks $\sigma_{A,t}$and for its firm-specific $\sigma_{F,t}$ and sector-specific $\sigma_{j,t}$ components from the manufacturing sector over the period 2001-2014, along with both analytical and bootstrap 95% confidence intervals, according to the variance decomposition (4), described in the main text.

Figure 5: Volatility of sales growth and its components in the Manufacturing Sector



Notes: This figure presents a decomposition of the firm-specific aggregate variance into two components that measure the contribution of firm-specific variances ($\sqrt{DIRECT_\tau}$) and of covariances across firms ($\sqrt{LINK_\tau}$). The decomposition is based on equation (5) of the main text.

Figure 6: Contribution of individual volatilities and covariance terms to firm-specific fluctuations

6 Conclusions

Using the Greek economy as a laboratory, we bring new evidence on microeconomic sources of aggregate fluctuations and, particularly, of large economic downturns caused by financial crises. We find that firm-specific shocks contributed substantially to the volatility of aggregate sales growth. This contribution became substantially larger during the crisis.

This paper also highlights the role of inter-firm networks in amplifying and propagating these firm-level idiosyncratic shocks through the aggregate economy. Throughout the sample period, firm linkages are two and a half times as important as the direct effect of firm-specific shocks in driving aggregate fluctuations. During the financial crisis, the Greek economy became more granular and the direct effect of firm-specific shocks had increased importance in driving aggregate volatility.

Our findings indicate that for a deep insight into the mechanics of large downturns associated with financial crises, it is important to model firm heterogeneity. In addition, it is important to study models that capture inter-firm network propagation mechanisms of idiosyncratic shocks to firms. Two notable papers with general equilibrium models that incorporate the production network propagation mechanism of microeconomic shocks are Barrot and Sauvagnat (2016) and Huneeus (2018). Moreover, Altinoglu (2020) analyzes contagion, via transmission of idiosyncratic shocks to firms, in financial networks.

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Appendix

A Data

The firm-level data are proprietary and they have been obtained from the ICAP Group, S.A., a private research company which collects detailed balance sheet and income statement data for SA and Ltd companies in Greece, together with their establishment date, location and ownership status, for credit risk evaluation and management consulting. ICAP data is used by commercial banks for credit decisions and by the central bank for credit rating information. Thus, the data are carefully controlled. Our dataset contains firm-level information for approximately 50,000 Greek firms operating in all sectors, except for banks and insurance companies, for the time period 2000 - 2014. For this paper we use information on gross sales, total balance-sheet assets, long-term and sort-term liabilities, year of establishment, and NACE rev. 2 codes.

We prepare the data for estimation in two stages. First, we clean the data from basic reporting mistakes. Second, we transform our dataset in order to be compatible with the methodology of di Giovanni et al. (2014).

In particular, we implement the following steps to clean the data:

1. We set to missing firm-year observations of gross sales that are negative.

2. We drop firm-year observations that have missing information on gross sales.

3. We audit for duplicates in our data.

4. We trimmed bottom and top 1% of the sales growth rates series to exclude extreme values from our analysis[14].

5. Following the methodology of di Giovanni et al. (2014), we restrict our sample to the intensive margin of aggregate sales growth by excluding firm-year observations where a firm is an entrant or an exiter.

To our knowledge, this is the first study to use so large and representative a firm-level dataset for the Greek economy. A natural question that might arise here is whether our firm-level dataset resembles the aggregate Greek economy. The coverage in our sample is consistently high. In particular, the ratio of aggregate gross output[15] recorded in our sample relative to the same variable in national level averages roughly 58 percent for the aggregate economy. This percentage is conservative because we have dropped observations with missing, zero, or negative values for gross sales. Gross output is taken from Eurostat, as reported by its Structural Business Statistics (SBS). The data in Eurostat are from Census sources and represent the universe of firms.

[14] Di Giovanni et al. (2014) dropped observations where the annual firm sales growth rate was less than −50% and greater than 200%. Since our datset covers the crisis era, i.e. a period of extremely negative growth rates, we cannot use the aforementioned cut-offs. Therefore, to exclude extreme values from our dataset we trimmed the bottom and top 1% of the observations of sales growths rates.

[15] Gross output is defined by the Bureau of Economic Analysis (BEA) as: "a measure of an industry's sales or receipts, which can include sales to final users in the economy (GDP) or sales to other industries (intermediate inputs). At the firm-level, gross output was measured by aggregate gross sales.

B Exporting Activity

	Greece	France	Sweden	EU
1998-2014	22.81	27.55	44.33	37.48
1998-2009	20.73	27.08	43.62	35.58
2010-2014	27.81	28.69	44.34	42.05

Source: World Bank

Table B: Exports as percentage of GDP