ΟΙΚΟΝΟΜΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS
ΣΧΟΛΗ ΟΙΚΟΝΟΜΙΚΩΝ ΕΠΙΣΤΗΜΩΝ SCHOOL OF ECONOMIC SCIENCES
ΤΜΗΜΑ ΟΙΚΟΝΟΜΙΚΗΣ ΕΠΙΣΤΗΜΗΣ DEPARTMENT OF ECONOMICS

Department of Economics
Athens University of Economics and Business

WORKING PAPER no. 08-2021

Firm Dynamics by Age and Size Classes and the Choice of Size Measure

Stelios Giannoulakis and Plutarchos Sakellaris

March 2021

Firm Dynamics by Age and Size Classes and the Choice of Size Measure

Stelios Giannoulakis[*,†] and Plutarchos Sakellaris[*,‡]

December 23, 2020

Abstract

The relationship of firm size and age to its growth and survival differs according to whether size is measured by sales or employment. Using a large and representative dataset of Greek firms over the period 1999-2014, we find the following patterns. Controlling for age, there is a strong negative growth-size relationship when measuring size with sales, but a strong positive one when measuring size with employment. Controlling for size, there is a positive monotonic survival-age relationship when measuring size with sales, whereas survival is negatively related with age for young firms when we measure size with employment. Our results indicate that public policies aimed at supporting Small and Medium-sized Enterprises (SMEs) should be specialized to the employment scale and the sales scale of enterprises, separately.

Keywords: Firm growth, Sales, Employment, Firm size, Firm age.

JEL Classification: D22, E23, E32, L21, L25, L26

Funding: This research was supported by Athens University of Economics and Business, and the State Scholarships Foundation (I.K.Y.) of Greece (grant number: 10-2-2-03-01).

Acknowledgments: We would like to thank George-Marios Angeletos, Stelios Arvanitis, Vangelis Dioikitopoulos, Christos Genakos, Pete Klenow, David Lagakos, Neil Mehrotra, Dino Palazzo, Tiago Tavares, Egon Zakrajsek, and seminar participants at Athens University of Economics and Business, the Hellenic Observatory at LSE, the Association of Southern-European Economic Theorists 2019 Conference, the 2019 Conference on Research on Economic Theory and Econometrics, for providing useful comments.

[*]Department of Economics, Athens University of Economics and Business.

[†]Macroprudential Policy Division, Directorate General Macroprudential Policy and Financial Stability, European Central Bank. Email: Stelios.Giannoulakis@ecb.europa.eu

[‡]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

When studying firm dynamics and survival by size and age groups, does it matter how size is measured? The answer is yes. In this paper, we study a large firm-level dataset that is representative of the Greek economy and find that it matters whether we measure firm size by sales or employment. Controlling for age, there is a strong negative growth-size relationship when measuring size with sales, but a strong positive one when measuring size with employment. Controlling for size, there is a positive monotonic survival-age relationship when measuring size with sales, whereas survival is negatively related with age for young firms when we measure size with employment. These results are robust and differ from the findings of Haltiwanger et al. (2013) for the US economy.

The role of firm size in its growth process is a long-standing question in the literature of firm and industry dynamics. Gibrat (1931) stated the so-called "law of proportionate effects", according to which the growth rate of a firm is independent of its size. Many empirical studies provided evidence either for or against Gibrat's Law (Heshmati, 2001; Calvo, 2006; Fotopoulos and Giotopoulos, 2010; Daunfeldt and Elert, 2013). The majority of those studies concluded that a negative growth-size relationship exists and this was considered a "statistical regularity" (Sutton, 1999 and Coad, 2007) up until a few years ago.

More recently, this "stylized fact" was disputed, when firm age was allowed to influence the growth-size relationship.[1] Haltiwanger et al. (2013) showed for the US economy that, after controlling for firm age, there is no systematic relationship between employment growth and size. We revisit this finding for the Greek economy. Using a novel and large firm-level dataset representative of the entire Greek economy over the period 1998-2014 and following closely the methodology of Haltiwanger et al. (2013), we examine the relationship of firm growth, survival, size and age. The contributions in this paper are based on four key aspects.

First, to the best of our knowledge, this is the first paper studying firm dynamics that contrasts sales and employment as size measures in the same dataset and controls for age. We find that firm sales and firm employment, lead to largely different growth-size relationships. In particular, we find a strong monotonic negative growth-size relationship for firm sales but a strong monotonic positive relationship for employment. In both cases, we control for firm age, which has been shown by Haltiwanger et al. (2013) to be crucial. We reject Gibrat's (1931) law, regardless of the indicator we employ. The growth-age relationship, after controlling for size effects, is negative for both size indicators. This finding is in accordance with both theoretical (Jovanovic, 1982; Hopenhayn, 1992; Ericson and Pakes, 1995; Arkolakis et al., 2018), and empirical literature (Evans, 1987; Hart and Oulton, 1996; Yasuda, 2005; Lopez-Garcia and Puente, 2012; Fort et al., 2013; Haltiwanger et al., 2013; Navaretti et al., 2014). We also examine whether the relationship of firm survival, size and age depends on whether size is measured with employment or sales. We find a strong

[1] Early studies in this topic had focused on the investigation of the growth-size relationship for particular age groups of firms such as startups and young firms (Calvo, 2006). A notable study is that of Lotti et al. (2007) in which the authors found that the impact of firm size on employment growth is fading as time passes and a firm ages and, therefore, Gibrat's law holds in the long run.

positive relationship between firm survival and firm size regardless of the size indicator used. This is in accordance with past literature (Jovanovic, 1982; Ericson and Pakes, 1995; Sutton, 1997; and Haltiwanger et al., 2013). In contrast, we find that the size indicator is crucial for the characterization of the survival-age relationship. Survival is positively related to age when we control for size measured with sales, whereas this relationship is negative for young firms when we control for employment size effects. The latter finding is at odds with evidence for the US economy in Haltiwanger et al. (2013).

Second, we explore sensitivity to the methodology of size classification. Methodological variations may be important for the analysis of firm growth patterns across firm age and size distributions (Delmar et al., 2003). Haltiwanger et al. (2013) assert that measurement is vital for the growth-size relationship. They find that, after controlling for age, there is no systematic relationship between employment growth and size when using the "base-year" size classification (i.e. the firm employment of the previous year). In contrast, they find a positive relationship when they classify with Davis et al.'s (1996) current average-size measure. These authors attributed this finding to the fact that the latter measure mitigates the impact of regression-to-the-mean effects. Our evidence for the Greek economy is different. We find that it is the variable used (sales vs. employment) and not its measurement methodology (base-year vs. DHS average-year) that matters for the different patterns in the growth-size relationship.

Third, we correct for econometric bias due to endogenous selection and sampling. Firm entry and exit leads to endogenous selection into our dataset. The fact that our dataset is not a Census may create sampling bias: smaller firms are less likely to be included. These two potential sources of bias are inherent in most datasets used in the literature that analyzes the size-growth relationship but the consequences are mostly ignored in practice. The recognition of the problem is not new. Mansfield (1962) found that firm selection creates the inverse relationship between growth and size. Hall (1987), Harhoff et al. (1998) and Marsili (2001) claimed that selection bias has only a small influence on the growth-size relationship. We deal with this double bias by employing a method due to Olley and Pakes (1996). Our empirical approach consists of two steps. Following Haltiwanger et al. (2013), we use fully-saturated econometric specifications to model the firm growth equation, with categorical independent variables for firm age and size. We augment these models with Olley and Pakes's (1996) correction term for selection and sampling bias. Under proper conditions, this bias can be approximated by a parametric functional form of the exogenous regressors of the growth equation and the predicted probability of a firm being in the sample. We obtain this predicted probability by a first-stage binary choice model, based on the work of Olley and Pakes (1996). This binary choice model gives us also the opportunity to investigate the impact of both firm size and age on the survival probability of a firm.

Fourth, our dataset includes observations on firm dynamics during a long stretch of euphoric growth (1999 to 2009) as wells as a persistent and severe economic depression (2010 to 2014). The Greek Depression that started in 2010 is perhaps the most severe and long-lived crisis that

a developed economy has experienced post-WWII.[2] This aspect of the dataset allows us to check whether the growth, survival, age and size relationships that we document change depending on aggregate conditions. We find that the financial crisis did not have a major effect on the patterns of firm dynamics by age and size in terms of either growth or survival.

There is good justification to measure firm size with either employment or sales. These two are the most widely used variables in empirical research on firm growth (Coad and Hölzl, 2010). Moreover, the two variables are not interchangeable measures of firm growth (Chandler et al., 2009). In Section 2, we document that a firm with high sales is not necessarily a big employer and vice versa. Employment conveys only part of the firm production process and the demand for its product. Of course, this part translates into job creation, which is vital for an economy and this explains the focus of the literature on it. On the other hand, sales is the equilibrium outcome of demand and supply for a firm's product. It captures the whole production process including firm decisions to substitute among the many different factors of production. Sales can reflect better than employment important firm characteristics that influence firm dynamics such as different capital intensities and the impact of intangible assets.

In the contemporary economy, competition is ever more driven by the development and accumulation of intangible assets – such as technological knowledge, brand, reputation, and customer base. These are important assets that may increase sales without a corresponding increase in labor. There is empirical evidence that enterprises with high intangible assets achieve high sales growth rates, without necessarily displaying high employment growth (Du and Temuri, 2014; Chandler et al., 2009; Delmar et al., 2003). Another important difference between the two variables is that sales is a more appropriate measure of firm growth for proprietorships, which constitute around 5% of firms in our sample. Theoretical models that try to explain the negative growth-size relationship by attributing it either to market selection and learning (Jovanovic, 1982; Hopenhayn, 1992; Ericson and Pakes, 1995; Arkolakis, 2016; Arkolakis et al., 2018), or to entrepreneurial choice under credit constraints (Evans and Jovanovic, 1989), or to idiosyncratic productivity shocks and firm market penetration choices (Arkolakis, 2016) concentrate their analysis on gross output and not on employment.

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 S.A. and Limited-liabilities 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 80,500 Greek firms operating in all sectors, except for banks and insurance companies, for the time period 1998 - 2014. To our knowledge, it is the first time that so large and representative a dataset is employed for the case of Greece. An important aspect of the dataset is that it includes

[2]For more information please see Gourinchas et al. (2017) and Chodorow-Reich et al. (2019)

proprietorships, one person" companies, start-ups, as well as information on firm age. This study examines the growth of firms of all age, employment and sales cohorts at both the intensive (continuing firm) and extensive (entrant and exiter) margins.

There is an important and large class of theoretical models that try to explain the growth-size and growth-age relationships, but they concentrate their analysis on the gross output of a firm (some examples are those of Jovanovic (1982), Hopenhayn (1992), Ericson and Pakes (1995), Arkolakis (2016) and Arkolakis et al. (2018)). However, there is lack of theoretical framework analyzing the employment growth-size relationship.[3] Our findings indicate that for a deeper insight of the firm growth patterns by size and age there is a need for theoretical models that capture the dynamics of employment and output separately.

Our findings also inform the policy debate on appropriate public policy for the support of enterprises. This has become even more important in the aftermath of the global financial crisis that erupted in 2008 or during the COVID-19 crisis. As an example, in the European Union many support programs are focused mainly on low-employment firms in an effort to boost aggregate employment.[4] However, our findings indicate that large firms, in terms of employment, both have a higher probability to survive and achieve more rapid employment growth during a crisis. Thus, they contribute importantly to aggregate employment and job creation. Our results also show that firm growth has completely different dynamics across the sales and the employment distributions. Public policies aimed at supporting Small and Medium-sized Enterprises (SMEs) should be designed according to separate sales and employment profiles of firms instead of joint sales-employment profiles.[5]

The remainder of the paper is structured as follows. Section 2 details the data used and the measurement methods for firm growth and size that are employed. Section 3 provides some stylized facts on the evolution of the growth of Greek firms during the period 1999-2014 along with some evidence on the growth-size and growth-age relationships over the same era. Section 4 presents the empirical methodology we follow. Section 5 includes the baseline estimation results, whilst Section 6 presents a sensitivity analysis of these results. Finally, Section 7 concludes.

[3]The few models that examine the linkage between employment growth and firm size are based on the assumption that employment is the unique input facror in the production function (see for instance Pakes and Ericson (1998) and Luttmer (2006)). Therefore, these models fail to capture the differences in capital intensities and intangible assets among firms, which may drive the different behavior of output and employment growth dynamics. Moreover, these model does not provide a theoretical explanation for the positive relationship between employment growth and firm size that we document in this study.

[4]See for instance the "EU policy framework on SMEs: State of play and challenges", retrieved from here.

[5]The definition of SMEs according to the EU recommendation 2003/361 is based on joint employment-turnover profiles. To the contrary, the definition of small businesses according to the U.S. Small Business Administration is much more flexible: it is based on separate sales and employment profiles that vary depending on the industrial sector to which each company belongs.

2 Data and Variables

2.1 Data Description

We employ a proprietary firm-level dataset obtained from ICAP Group, S.A., a private research company that collects and maintains detailed accounting and employment information for S.A. and Limited-Liability companies in Greece. The data set has financial accounting information from detailed balance sheets and income statements, along with detailed information for employment, establishment date, location and ownership status of firms. All Greek companies are required by law 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 annual firm-level information for approximately 80,500 Greek firms operating in all sectors, except for banks and insurance companies, for the time period 1998 - 2014. This time period allows us to examine firm dynamics in the Greek economy during a boom (1998-2008) as well as during the severe Depression that followed (2009-2014). Roughly 99.5% of companies in the data set are private, in contrast with other widely used datasets, such as Compustat for the US, that contain information only from large publicly listed firms. For this paper we use information on gross sales, employment, year of establishment, two-digit NACE Rev. 2 industry classification codes and firm location[6]. Details on the cleaning procedures for the firm-level data can be found in Appendix A.

The aggregate data and deflators for Greece are collected from two publicly available sources: the Eurostat (Structural Business Statistics) and the Organization for Economic Cooperation and Development (OECD) databases.

To our knowledge, this paper is the first to use so large a firm-level dataset for the Greek economy. A natural question that might arise is whether our firm-level dataset is representative of the aggregate Greek economy. Table 1 summarizes the coverage in our data compared to the aggregate economy between 1998 and 2014. The columns in the table represent the ratio of gross output and aggregate employment recorded in our sample relative to the same object in Eurostat as reported by its Structural Business Statistics (SBS).[7] The data in Eurostat are from census sources and represent the universe of Greek firms. As Table 1 shows, the coverage in our sample is consistently high for gross output: it averages roughly 60 percent for the aggregate economy. The coverage for aggregate employment is lower: it averages roughly 34 percent for the aggregate economy. These coverage statistics are conservative because we drop observations with missing,

[6]The Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE, is the industry standard classification system used in the European Union. The current version is revision 2 (Rev. 2) and was established by Regulation (EC) No 1893/2006. It is the European implementation of the United Nations' International Standard Industrial Classification (ISIC) of all Economic Activities, revision 4.

[7]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 is measured by aggregate gross sales.

zero, or negative values for gross sales and missing or negative values for employment.

Although the coverage for employment is relatively low for the aggregate economy, it is high for some important sectors of the economy. Table 2 presents the average coverage in our data by sector over the period 1998 to 2014, along with the share of each sector in the aggregate gross output and employment.[8] Three sectors roughly the 70 percent of the economic activity. These are "Manufacturing", "Trade, Transportation and Accommodation", and "Services". The coverage in the "Manufacturing" sector is high for both gross output (82 percent) and employment (71 percent). In the "Trade, Transportation and Accommodation" sector, coverage is high for gross output (79 percent) and above average for employment (42 percent). To the contrary, coverage for the sector of "Services" is low for both variables. To ensure the robustness of our results, we conduct our analysis for the whole sample, on which we base our main results, and then we repeat the analysis for the "Manufacturing" and "Trade, Transportation and Accommodation" sectors. Moreover, we correct for possible endogenous selection and sampling biases using the econometric methodology of Olley and Pakes' (1996) or, alternatively, that of Heckman (1979).

******* Insert Tables 1 and 2 here *******

Figure 1 plots aggregate gross output and aggregate employment in our ICAP data set for the time period 1998-2014. It compares the aggregated quantities from our dataset to the respective aggregates as recorded by Eurostat. As we can see, both series in our sample mimic aggregate activity well. The trajectories of both total firm sales and total firm employment track closely the trajectories of gross output and employment at the macro-level, respectively.

******* Insert Figure 1 here *******

2.2 Variables and Measurement

The literature of firm growth dynamics has used a variety of variables for firm size as well as formulas for measuring growth. Delmar et al. (2003) have shown that the choices of variables and measures may be important for analyses of firm growth. In this study, we analyze firm growth patterns differentiated by firm size and age distributions and find that the results depend on the firm size indicator used. We employ two alternative size indicators: sales and employment. We focus on these indicators for two reasons. First, they are the most widely used variables in empirical research on firm growth (Coad and Hölzl, 2010). Second, these two variables are not interchangeable in measuring firm growth (Chandler et al., 2009). Each variable paints a different picture of firm size.

Labor is but one of the production inputs. Thus, employment conveys only part of the firm production process and the demand for its product. Of course, this part translates into job creation, which is vital for an economy and this explains the focus of the literature on it. On the other hand,

[8] Sectors have been classified according to their two-digit NACE Rev. 2 codes

sales is the equilibrium outcome of demand and supply for a firm's product. It captures the whole production process including firm decisions to substitute among the many different factors of production. Sales can reflect better than employment important firm characteristics that influence firm dynamics such as different capital intensities and the impact of intangible assets. In the contemporary economy, competition is ever more driven by the development and accumulation of intangible assets – such as technological knowledge, brand, reputation, and customer base. These are important assets that may increase sales without a corresponding increase in labor. There is empirical evidence that enterprises with high intangible assets achieve high sales growth rates, without necessarily displaying high employment growth (Du and Temuri, 2014; Chandler et al., 2009; Delmar et al., 2003). Another important difference between the two variables is that sales is a more appropriate measure of firm growth for proprietorships, which constitute around 5% of firms in our sample.

Employment may be more robust for measuring the growth of small enterprises, since this group of companies is more likely to conceal sales than labor from tax authorities for tax evasion purposes (Coad and Hölzl, 2010). Also, sales do not always lead the growth process. For high-technology start-ups, and the start-up of new activities in established firms, it is possible that assets and employment will grow before any sales occur (Delmar et al., 2003). Despite some drawbacks in using either one of the two indicators in the analysis of firm growth patterns by age and size, the literature has found them to be the most appropriate ones. [9]

There are also different formulas for measuring growth rates, whether of sales or employment. We use two alternative measures of firm growth rates in our analysis. First, we define the annual firm growth rate, $g_{i,t}$, as the logarithmic difference $\Delta lnS_{i,t}$ where $S_{i,t}$ denotes the size of firm i at period t. In our analysis, the classification of firms into size categories uses either either gross sales of firm i at period $t-1$, deflated by the relevant Producer Price Index (PPI), or by the number of employees of firm i at period $t-1$ ("base-year" classification of firm size).

In a list of 10 alternative measures for growth rates surveyed by Tornqvist et al. (1985), the log difference measure was found to be the most preferable measure of relative change as it is the only one that is symmetric, additive and normed. An important drawback of log differences as a measure of relative change, however, is that it is not defined for exiting and entering firms with $S_{i,t} = 0$ and $S_{i,t-1} = 0$, respectively. For this reason, we employ as an alternative measure for firm growth the Davis et al. (1996) bounded growth rates (DHS hereafter):

$$g_{i,t} = \frac{(S_{i,t} - S_{i,t-1})}{\frac{1}{2}(S_{i,t} + S_{i,t-1})}$$

[9] Other indicators have more important limitations (Delmar et al., 2003). For instance, such indicators as market share and physical output can only be compared within industries for firms with a similar product range. Total assets depend highly on the capital intensity of the industry and thus are very sensitive to changes over time. Also, profits are more of a financial than an economic variable, and the relationship to size is only evident in aggregates or over long periods for individual firms. For these reasons, sales and employment are the most widely used variables in empirical growth research (Coad and Hölzl, 2010).

We combine the DHS measure for firm growth with the related "average-size" measure for classifying firm size, as proposed by Davis et al. (1996). The DHS average-size measure that we use is based on the average of sales or employment in years $t-1$ and t. The DHS measure for firm growth, combined with the corresponding average-size measure, has some important advantages. First, it mitigates potential "regression-to-the-mean" effects.[10] Second, it is defined for both entrants and exiters allowing us to examine the role of the extensive margin in the firm growth dynamics. Finally, it allows us to compare our results for employment with those of Haltiwanger et al. (2013). Therefore, in this study, we employ two variables for firm size (sales or employment), two measures for firm growth (logarithmic differences of the size indicator or the DHS measure) with the corresponding measures for classifying firms into size groups("base-year" or "average-year" firm size, respectively).

Regarding firm age, this is defined as the difference between the current year of operation and the year of establishment for each firm. For start-up firms, age is set equal to one. An important advantage of our dataset is that ICAP's information for the year of establishment comes from administrative records.

3 Stylized Facts on Firm Dynamics by Age and Size Category.

In this section, we present some stylized facts on the evolution of firm sales growth and of firm employment growth in Greece during the period 1998-2014, focusing on the impact of firm age and size on these dynamics. A matter of high importance in the analysis of firm growth dynamics, highlighted very early in the literature by Mansfield (1962), is the "selection effect or bias" that the firm entry-exit process creates. In order to investigate the role of selection bias on firm growth, we examine the relationship of age and size on both unconditional and conditional firm growth rates, the latter applying to firms that survived until 2014 (i.e. the last available year in our sample).

Figure 2 presents the dynamic patterns of the average annual firm growth rates of Greek firms for the time period 1999-2014. Panel (a) displays the patterns of sales growth, whilst Panel (b) the patterns of employment growth. In order to investigate whether the growth rates of the firm-level data resemble the growth path of the Greek economy, we also include the growth rates of Gross Domestic Product (GDP) annual time series in Panel (a) and the growth rates of aggregate employment annual time series in Panel (b), as reported in the OECD Database. We can discern two phases of the economic cycle: the "boom" (1998-2009) and the "depression" one (2010-2014). The course of conditional firm growth is quite similar to that of GDP. The 2008 global financial crisis led to a dramatic fall of both firm and aggregate growth and economic activity deteriorated further with the eruption of the Greek financial crisis. In 2014, an anaemic recovery can be observed

[10] Haltiwanger et al. (2013) note that firms that recently experienced negative transitory shocks (or even transitory measurement error) are more likely to grow, while businesses recently experiencing positive transitory shocks are more likely to shrink. This "regression-to-the-mean" effect is particularly important when studying the business size–growth relationship.

in both GDP and firm growth rates. Even though the trajectory of the conditional firm growth is very close to that of GDP, the unconditional firm growth has a more divergent and unstable path, a fact that underlines the importance of sample selection in the analysis of firm dynamics. The two phases of the cycle can be clearly observed in Panel (b) as well.

******* Insert Figure 2 here *******

We now turn to exploring whether the firm growth patterns vary by age and size over the cycle. To simplify the analysis, we consider broad firm age and size groups. Specifically, following Fort et al. (2013) we separate firms into two age groups: firms are "young" if they are less than 6 years old and "mature" if they are 6 years old or older. Twenty three (23) percent of firms in our sample are young. Regarding firm size, we classify firms according to their size in period t-1. When using sales as indicator of size, we create three groups: "small" for percentiles 1-50, "medium" for percentiles 51-90 and "large" for the percentiles 91-100.[11] When using employment as indicator of size, we classify firms into the following three groups: "small" for firm with less than 20 employees, "medium" for firms with 20-49 employees and "large" for firms with more than 50 employees.[12]

Figure 3 illustrates the dynamic patterns of average sales growth (Panel (a)) and of average employment growth (Panel (b)) of young and mature Greek firms over the period 1999-2014. Two observations emerge. First, both sales and employment growth rates are significantly higher for young firms than for their mature counterparts. Second, both age groups exhibit considerable cyclicality: the eruption of the Greek financial crisis led to a sharp decline in the growth rates of both young and mature enterprises.

******* Insert Figure 3 here *******

Figure 4 shows sales (Panel (a)) and employment (Panel (b)) growth rates by firm size groups. Several observations emerge. Sales growth rates are significantly higher for small than for large firms. Both sales size groups exhibit considerable cyclicality, and small firms contracted more sharply during the Greek Depression. However, employment growth dynamics are completely different. First, net employment growth rates are higher for large than for small firms. Second, although low employment firms exhibit considerable cyclicality, it is striking that high employment enterprises continued to expand even during the crisis.

******* Insert Figure 4 here ********

To understand the difference between sales and employment growth dynamics by size category, a critical question is whether a large firm in terms of sales is also large in terms of employment

[11] Under this size classification a firm is considered "small" if its annual gross sales are less than € 750,000, "medium" if its sales are more than € 750,000 and less than € 6,500,000 and "large" if its gross sales are more than € 6,500,000.

[12] Under this size classification the largest group contains roughly 8% of employment observations. Thus, the population of the group of large companies is very close to that under the sales classification. In any case, employment growth patterns by firm size remain largely the same even when we use the same classification as for sales: "small" for percentiles 1-50 of the employment distribution of period $t-1$, "medium" for percentiles 51-90 and "large" for percentiles 91-100.

and vice versa. Table 3 reports the distribution of firms by sales and employment size groups. Only half (52.5%) of large firms in terms of sales are also large in terms of employment. Similarly, although the majority (62%) of large firms in terms of employment are also large in terms of sales, a very large portion of these firms are medium (31.5%) or even small (6.5%) in terms of sales. In the same spirit, although the majority (69.5%) of small firms in terms of employment are also small in terms of sales, a large portion of these firms are medium (29%) or large (1.5%) in terms of sales. Similarly, one quarter of small firms in terms of sales are medium in terms of employment.[13] Therefore, firms with high sales do not necessarily employ many workers and vice versa.[14] This observation is important in the debate about the role of firm size on firm growth. Sales and employment can paint a different picture of the firm. The rest of the paper is a rigorous examination of this difference in sales and employment growth dynamics by size.

******* Insert Table 3 here *******

It is important to discuss entry and exit of firms in our sample. Figure 5, Panel (a), displays the evolution of the number of firms in our sample. The number of firms decreased substantially after the onset of the Greek financial crisis (by 20% from 2010 to 2013). Panel (b) shows that this decline in firm numbers during the crisis was driven by the increased rate of exiting firms. Before the financial crisis, the number of entries exceeded the number of exits. This was reversed during the crisis. Panels (c) and (d) present the number of exiting firms in the data by age and size groups. As we can see, the incidence of entry and exit varies substantially by age and size.The majority of exiting firms were small or young. It seems that firm age or size was a good indicator for firm survival during the Greek Depression.

We would like to stress that, since our dataset is not a Census of the Greek economy, the entry and exit rates displayed in this Figure do not correspond only to economic decisions to start a business or close it. They also include a portion that reflects selection into the sample. Both economic survival and sample selection introduce potential bias in inferences based on Figure 5. The econometric methodology we follow in this study enables us to correct for selection bias due to both business starts and failures and the sampling procedure. This methodology will be presented in the following section. The importance of endogenous entry-exit decisions (that create a "selection bias") for firm dynamics has been pointed out in the literature (e.g. Mansfield, 1962; Evans, 1987; Hall, 1987).

******* Insert Figure 5 here *******

From the above analysis, it seems that firm size and firm age play a crucial role in firm growth. Firm age seems to have a similar negative relationship with both sales and employment growth rates. However, we found that there are striking differences in the relationship of firm size with sales or employment growth. In addition, the entry-exit channel seems to be an important factor

[13] In Appendix B (Table B1) we present the same analysis for more granular sales and employment classes.
[14] In our sample, the correlation between sales and employment is 0.544.

for the analysis of the growth trajectories by age and size over the cycle. In the next section, we shed light on these facts.

4 Empirical Specification and Identification

In order to quantify the relationships between firm growth (in terms of either sales or employment) and firm size and age, we use a non-parametric regression approach based on Haltiwanger et al. (2013). Specifically, we employ the following econometric specification:

$$g_{i,t} = \beta_0 + f(A^k_{i,t}, S^j_{i,t}; \beta) + \xi_{i,t} \tag{1}$$

$g_{i,t}$ denotes the growth rate of firm i at period t, $A^k_{i,t}$ is a categorical variable for age with values 1-6 for age groups K={1-3, 4-6, 7-10, 11-15, 16-20, 20^+ years}, and $S^j_{i,t}$ is a categorical variable for size with values 1-6 for sales size groups J={1-30, 31-60, 61-70, 71-80, 81-90, 91-100 percentiles} or the values 1-6 for employment size groups J={1-4, 5-9, 10-19, 20-49, 50-99, 100^+ employees}.[15] $f(A^k_{i,t}, S^j_{i,t}; \beta)$ is a linear function of the two variables $A^k_{i,t}$ and $S^j_{i,t}$ together with complete interactions between them.[16] This functional form allows us to capture not only the effects of age and size on the patterns of firm growth, but also the age-size interaction effects on these paths.[17]

Selection bias is an important statistical concern in estimating the above econometric specification that we need to address. Bias may arise from endogenous firm selection due to starting or closing a business, or from the sampling design and procedure of our dataset, which, while being representative of the aggregate Greek economy, is not a census. The vital role of this problem in the analysis of firm dynamics has been pointed out early in the literature on firm growth (e.g. Mansfield, 1962; Evans, 1987; Hall, 1987). We address this issue by employing the methodology of Olley and Pakes (1996). Selection into the sample introduces a bias term in equation (1) as follows:

$$E[g_{i,t} \mid S^j_{i,t}, A^k_{i,t}, y_{i,t} = 1] = \beta_0 + f(A^k_{i,t}, S^j_{i,t}; \beta) + E[\xi_{i,t} \mid S^j_{i,t}, A^k_{i,t}, y_{i,t} = 1] \tag{2}$$

where $y_{i,t}$ is an indicator function that receives the value 1 if firm i is active in period t and 0 otherwise.

The last term is the *bias term* due to endogenous selection and sampling. Following Olley

[15] In Table B1 (Appendix B), we explore the cross-classification of firms in these sales and employment size groups. As mentioned in the previous section, firms with high sales do not necessarily have high employment or vice versa.

[16] Specifically:

$$f(A^k_{i,t}, S^j_{i,t}; \beta) = \sum_{j=1}^{J} \beta_{1,j} S^j_{i,t} + \sum_{k=1}^{K} \beta_{2,k} A^k_{i,t} + \sum_{j=1}^{J} \sum_{k=1}^{K} \beta_{3,j,k} (S^j \times A^k)_{i,t}$$

[17] Haltiwanger et al. (2013) demonstrated that for the proper characterization of the growth-size (growth-age) relationship we have to control for age (size). For this reason, the inclusion of the age-size interaction terms in our model is crucial.

and Pakes (1996), we consider this *bias term* as a function of the explanatory variables and the probability of being in the dataset at period t. Specifically,

$$E[\xi_{i,t} \mid S^j_{i,t}, A^k_{i,t}, y_{i,t} = 1] \approx h(S^j_{i,t}, A^k_{i,t}, S^j_{i,t-1}, A^k_{i,t-1}, \hat{P}_{i,t}). \tag{3}$$

We assume a first-order polynomial expansion in $(S^j_{i,t}, A^k_{i,t}, S^j_{i,t-1}, A^k_{i,t-1}, \hat{P}_{i,t})$ of function $h(.)$.

We obtain the probability of being in the dataset at period t by estimating the following binary choice model:

$$Pr(y_{i,t} = 1) = \Phi\left(\alpha_0 + f(A^k_{i,t}, S^j_{i,t}; a) + \mu_{i,t}\right) \tag{4}$$

We assume normal disturbances, i.e. $\mu_{i,t} \sim N(0, \sigma^2_\mu)$. The estimation of this model gives us also the opportunity to investigate the impact of both firm size and age on the survival probability.

Since firm size and firm age distributions vary by industry as the growth rate patterns do as well (Daunfeldt and Elert, 2013), we control for detailed industry fixed effects.[18] Additionally, we control for location fixed effects by employing a set of prefecture dummies.[19] Both industry and location dummies allows us to capture (a part of) the ex-ante firm heterogeneity. In the same spirit, we include the industry and location fixed effects in the first-stage survival equation (4).

The econometric specification (2) is a fully saturated dummy variable model. Therefore, following Haltiwanger et al. (2013), we estimate the econometric specification (2) using OLS with heteroskedasticity and autocorrelation consistent (HAC) standard errors. In order to deal with both the endogenous selection and sampling biases we augment the set of regressors with the predicted probability of a firm remaining in the sample like in Olley and Pakes (1996). To ensure the validity of our estimates, we also estimate the econometric specification (2) using Heckman's (1979) two-step approach for selection bias correction instead of the Olley and Pakes (1996) approach. Heckman's (1979) approach leads to the same growth-age and growth-size relationships with our baseline approach for both sales and employment.[20]

5 Estimation Results

5.1 Growth-Age and Growth-Size Relationships

The primary objective of this study is to disentangle the role of firm size and age in firm growth measured either by employment or sales. To this end, we estimate four alternative versions of model (2), two for firm sales and two for firm employment. First, we calculate growth using the logarithmic difference of deflated sales as a measure of firm sales growth and the base-year

[18] For the classication of firms at industries we use the two-digit NACE Rev. 2 codes. This classification leads to 97 industrial sectors of economic activity.

[19] ICAP database provides us information about the firm location among the 52 prefectures of Greece.

[20] See section 6.3 for more details.

classification of firm size (i.e. the logarithm of deflated sales at period $t-1$). We denote this measure as the "traditional" one. Second, we calculate growth employing the Davis et al.'s (1996) definitions for firm sales growth rates and firm size, defined earlier in subsection 2.2. We denote this as the "DHS" measure. Third, we calculate growth using the "traditional" measure for employment growth and base-year classification for firm size. Finally, we estimate model (2) for employment using the "DHS" measure for employment growth rates and size.

Since model (2) consists of categorical variables and especially since these variables are interacted, the regression coefficient estimates do not capture the partial effect of firm age or size on firm growth (Williams, 2012). Therefore, following Haltiwanger et al. (2013), we present marginal effects at means (MEMs) instead of regression coefficients, in order to capture properly the partial effects of both firm age and size on firm growth. MEMs of firm size from model (2) are computed by holding the age distribution of sales (or employment) constant at the sample mean. MEMs of firm age are analogously computed by holding the size distribution of sales (or employment) constant at the sample mean.

We present our estimation results using figures. To facilitate comparisons between employment and sales, we focus on comparing the differences in effects relative to a baseline or omitted group. The baseline group for size consists of the largest firms whereas for age it consists of the oldest firms.[21]

Figure 6 displays the MEMs of firm age (Panel (a)) and firm size (Panel (b)) from econometric specification (2). Beginning with the main results in the upper panel, the plotted curve shows a strong negative relationship between firm age and firm growth when we control for firm size, regardless of the measure of firm size (sales or employment). The average annual rate of sales growth of the youngest enterprises is about 11.1 percentage points higher than that for the oldest firms, whilst the average annual rate of employment growth of the youngest enterprises is about 18.8 percentage points higher than that for the oldest firms. These effects decline more or less monotonically as the age of the firm increases. The relative sales growth premium for being young declines to 8.4% and 3.4% for age classes 4–6 and 7–10 years, respectively (the corresponding employment growth premia for being young for these two age classes are 11.1% and 5.9%, respectively). When we employ the "DHS" measurement, the pattern of the growth-age relationship for both sales and employment is similar: negative and more or less monotonic. Notably, this relationship becomes stronger, especially for sales, a fact that suggests an important role of entering and exiting firms in the firm growth trajectories.

Now we turn to Panel (b). The panel reveals a strong negative monotonic relationship between firm size and firm sales growth when we control for firm age. The average annual rate of sales growth of the smallest enterprises is about 9.9 percentage points higher than that for the largest firms. The downward curve is much steeper for smaller size classes (1-60 percentiles of sales

[21] The estimated marginal effects with their standard errors for the growth model (2) can be found in Table C1, Appendix C. All coefficients are statistically significant at the 1% level. The estimated differences in MEMs relative to a baseline group, that are depicted in figure 6, can be found in Table C2, Appendix C.

distribution) implying a much stronger negative size effect for small relative to large firms. The effect declines clearly monotonically as the size of the firm increases: the relative sales growth premium for being small declines to 2.7% and 1.1% for size classes 2 and 3, respectively. We find an even stronger inverse monotonic sales growth-size relationship when we include the extensive margin in our analysis through the DHS measurement.

The patterns change dramatically when we measure firm growth by employment rather than sales. More specifically, we observe a systematic and strong positive monotonic relationship between firm employment growth and firm size. The average annual rate of employment growth of the smallest enterprises is about 14.5 percentage points lower than that for the largest firms, whilst the relative employment growth discount for being small declines to 5.4% and 4.5% for size classes 5-9 and 10-19 employees, respectively. The "DHS" measure moderates this positive growth-age relationship (the average annual rate of employment growth of the smallest enterprises is about 6.6 percentage points lower than that for the largest firms), but it still remains positive and monotonic. The reason for that is that the "DHS" measurement mitigates the "regression-to-the-mean" effect and, as a result, it moderates the size effect on firm growth (see Haltiwanger et al., 2013 for a discussion of the the "regression-to-the-mean" effect).

******* Insert Figure 6 here *******

Several remarks can be made about these empirical findings. First, there is a clear negative relationship of both sales and employment growth rates with firm age after controlling for size effects. These patterns are consistent with predictions in models in which firm dynamics are attributed either to market selection and learning (see Jovanovic, 1982; Hopenhayn, 1992; Ericson and Pakes, 1995; Arkolakis et al., 2018), to entrepreneurial choice under credit constraints (Evans and Jovanovic, 1989), or to idiosyncratic productivity shocks and firm market penetration choices (Arkolakis, 2016). Second, we find a strong monotonic negative sales growth-size relationship, after controlling for age effects. There are many empirical studies (Evans, 1987; Hart and Oulton, 1996; Yasuda, 2005; Bentzen et al., 2012) and theoretical models (Jovanovic, 1982; Hopenhayn, 1992; Arkolakis, 2016) that support this finding, though they do not always control for age.

However, the size-growth relationship is completely different when we use employment rather than sales as a measure of size and business dynamics. Haltiwanger et al. (2013), using employment data for the US economy and the "traditional" measure for firm size, show that there is no systematic relationship between firm size and growth, once age is taken into account. They also find a positive employment growth-size relationship, after controlling for age, under the "DHS" measurement. In contrast, our results reveal a clear positive employment growth-size relationship after controlling for age, that declines monotonically as firm employment increases, regardless of the type of measurement.

There is an important and large class of theoretical models that analyze the growth-size relationship, but they focus only on gross output or sales and not on employment (Jovanovic, 1982; Hopenhayn, 1992; Ericson and Pakes, 1995; Arkolakis, 2016; Arkolakis et al., 2018). Our findings

indicate that for a deeper insight in firm growth mechanics there is a need for theoretical models that analyze sales and employment growth separately, since firm dynamics display different patterns depending on the measure of size used.

This different impact can be attributed to the fact that each variable draws a different picture of the growth potentials of a firm. Although employment reflects only one part of the production process, sales encapsulate the whole process. For instance, sales can capture differences in capital intensity among firms along with the differences in employment (Delmar et al., 2003). Moreover, sales can identify the role of intangible assets in the growth process of a firm. There is recent empirical evidence that enterprises with high intangible assets achieve high sales growth rates, without necessarily being employment-intensive companies (Du and Temuri, 2014). Finally, we note that, regardless of the growth indicator we use (sales or employment) and the type of the measurement ("traditional" or "DHS"), we have clear rejection of the weak form of Gibrat's law, according to which the mean growth rate of a firm is independent of its size.

5.2 Firm Survival by Age and Size

The estimation of the first-stage survival model (4) allows us to investigate the impact of both firm size (measured either by sales or employment) and age on firm survival probability. We estimate four alternative versions of model (4), two for firm sales and two for firm employment. First, we use the base-year definition of firm size in terms of sales (we call this "traditional"). Second, we employ the Davis et al.'s (1996) definition for firm size in terms of sales (we call this "DHS"). Third, we utilize the "traditional" measure for firm size in terms of employment. Finally, we estimate model (4) using employment and the "DHS" measure for firm size.

Since binary choice model (4) consists of categorical variables and their interactions, we present marginal effects at means (MEMs) in order to convey the partial effects of both firm age and size on firm survival (see Williams, 2012 for a discussion). We present MEMs in a series of Figures.[22] To facilitate comparisons between employment and sales, we focus on comparing the differences in effects relative to a baseline or omitted group. As before, this is the group of largest or oldest firms.[23]

Figure 7 presents the relationships between survival probability and firm size (Panel (a)) or age (Panel (b)). Again, we conduct our analysis for firm sales and firm employment separately. Beginning with the results using the "traditional" measure, the plotted curve in Panel (a) shows a positive monotonic relationship between firm size and firm survival when we control for firm age. This is so, regardless of the measure of firm size (although the relationship is stronger for employment, at least for small businesses). The average survival probability in the largest size class is about 13.4 percentage points higher than that for the smallest firms classified by sales, whilst this difference is about 16.4 percentage points classified by employment. The effect

[22] All standard errors are below 0.01, thus all MEMs coefficients are significant at the 1% level.

[23] The estimated differences in MEMs relative to the baseline group, that are depicted in figure 7, can be found in Table C3, Appendix C.

declines monotonically as firm size increases. The survival premium for being large declines to 8.6% and 4.8% for sales percentiles 31-60 and 61-70, respectively. The corresponding employment growth premia for being large are 9.8% and 5.7% for employment classes 5-9 employees and 10-19 employees, respectively. Under the "DHS" measure, the survival-size relationship remains strongly positive and monotonic, though somewhat subdued. Thus, a robust finding is that large firms are more likely to survive than smaller firms, regardless of the type of measure.[24]

Now we turn to the age-survival relationship (Panel (b), Figure 7). Survival probabilities have smaller differences across age classes than we had found across size classes. Panel (b) illustrates that, under both measures, there is a positive weakly monotonic relationship between firm age and survival when we control for firm sales. The average survival probability in the highest age class is only 2.5 percentage points higher than that for the youngest firms. However, controlling for employment instead of sales, these patterns change dramatically. More specifically, once we control for employment, we observe a systematic negative weakly monotonic relationship between firm survival and age for young firms (i.e. those with age less than 10 years) and a non-monotonic and very weak positive relationship for older firms. This finding for the Greek economy is at odds with the results of Haltiwanger et al. (2013) for the US economy, according to which young firms have much higher firm exit rates (and thus lower survival rates) than more mature firms do. We find the same survival-age patterns for employment, regardless of whether we use the traditional or DHS measure. To sum up, we find a monotonic negative size-survival relationship, regardless of the indicator and the measure that we use for firm size. However, the age-survival relationship highly depends on the indicator that we use for the firm size: it is positive and monotonic for firm sales for all ages of firms, but negative for firm employment for young firms.

******* Insert Figure 7 here *******

6 Sensitivity Analysis

In this section, we examine the robustness of our results. To this end, we perform three sensitivity exercises. First, we check whether the different coverage in our dataset of sales versus employment affects the results. Second, we explore whether our results are affected by the sample including the Greek Depression (2010-2014), one of the harshest crises ever faced by a developed economy. Finally, we examine whether our results are robust to using a different method for correcting selection bias.

[24] There is previous empirical evidence that conforms with this finding (see for instance the seminal paper of Sutton (1997) and Haltiwanger et al. (2013)). Also there is theoretical literature that provides arguments for this result (e.g. Jovanovic, 1982; Ericson and Pakes, 1995).

6.1 Firm Growth Patterns by Sector

An issue of concern is that our dataset has higher coverage for sales than for employment (60% and 34%, respectively) when compared to the aggregate economy. In a previous section, we argued that our dataset is representative of the whole economy as it tracks closely aggregate dynamics. Furthermore, to the best of our knowledge, it is the largest firm-level dataset ever used for the Greek economy. To check further whether different coverage rates affect our results, we repeat our analysis for two sectors. These are the "Manufacturing" sector, which has high coverage for both sales and employment (82% and 71%, respectively), and the "Trade, Transportation and Accommodation" sector, which has high coverage for sales but a lower rate for employment (79% and 42%, respectively).

Figure 8 displays the estimation results for the "Manufacturing" (upper panels) and "Trade, Transportation and Accommodation" (bottom panels) sectors. Both sales and employment growth patterns by age and size are very similar with those for the whole economy (Figure 6). These results make us confident that our dataset is appropriate for analyzing firm dynamics with either indicator of firm size. They also give us confidence in the econometric method we employ to correct for selection bias.

******* Insert Figure 8 here *******

6.2 The Impact of the Greek Depression

Our dataset includes the period of the Greek Depression (2010-2014), one of the harshest crises faced by a developed economy. A natural question is whether the financial crisis affected the growth patterns of Greek firms across the age and size distributions. In other words, to what extent did the different growth-size relationship between sales and employment stem for the financial crisis?

To answer this question, we repeat our analysis for the pre-crisis period (1999-2009). Figure 9 displays the estimation results for this alternative sample period. Both sales and employment growth patterns by age and size are very similar with those for the complete sample period (Figure 6). We conclude that the severe financial crisis that started in 2010 is not responsible for the opposite pattern of growth-size relationship between sales and employment.

******* Insert Figure 9 here *******

6.3 Alternative Correction for the Sampling Bias

In order to deal with endogenous firm selection due to entry and exit and sampling bias due to the design of our dataset, we employed the method of Olley and Pakes (1996). In order to examine robustness of this approach, we estimate again the econometric specification (2) using Heckman's (1979) two-step approach for selection bias correction. More specifically, following Wooldridge's

(2002) generalization of Heckman's (1979) methodology for panel data we can approximate the *bias term* in equation (2) as follows:

$$E[\xi_{i,t} \mid y_{i,t} = 1] \approx \gamma IMR_{i,t} \tag{5}$$

where γ is a constant term and the $IMR_{i,t}$ is the inversed Mill's ratio which is given by,

$$IMR_{i,t} = \frac{\varphi_{i,t}}{\Phi_{i,t}}$$

where $\varphi_{i,t}$ and $\Phi_{i,t}$ denote the survival probability of firm i in year t and its probability density, respectively. Under suitable assumptions, we can obtain consistent estimates of these quantities by using the Probit model (4), described in section 4.

We augment the econometric specification (2) with $IMR_{i,t}$ as an extra regressor, instead of the parametric specification $h(S^j_{i,t}, A^k_{i,t}, S^j_{i,t-1}, A^k_{i,t-1}, \hat{P}_{i,t})$ (see equation (3)) of the Olley and Pakes (1996) approach. This extra regressor corrects for both selection and sampling biases. Figure 10 illustrates the estimation results according to Heckman's (1979) methodology. Both sales and employment growth patterns by age and size are very similar with those of the baseline approach (Figure 6).

******* Insert Figure 10 here *******

7 Conclusions

Using a large and representative dataset on Greek firms covering all sectors of the economy over the period 1999-2014, we bring new evidence on the patterns of firm growth and firm survival across the age and size distributions. Our findings reveal the importance of the growth indicator used in the analysis: different indicators lead to starkly different growth-size and survival-age relationships. Specifically, we find a strong negative growth-size relationship for firm sales, but a strong positive monotonic relationship for firm employment. In both cases, we control for age effects. Regarding firm age, we find a negative growth-age relationship, after controlling for size effects, regardless of the growth indicator we use. Moreover, there is a monotonic positive survival-size relationship, after controlling for age effects, regardless of the size indicator we use. Finally, the survival-age relationship positive when sales is used as the indicator of size, whereas the relationship is negative for young firms when size is measured by employment.

Our findings are useful for both academics and policymakers. First, although there is an important and large class of theoretical models that explain the negative sales growth-size relationship, there is no theoretical framework that produces a positive employment growth-size relationship. Our findings indicate that for a deeper insight of the firm growth patterns by size and age there is a need for theoretical models that capture the dynamics of both employment and output (sales) separately, since sales and employment lead to completely different growth-size patterns. Second,

our results indicate that policy makers should design supportive policies for enterprises according to separate sales and employment firm profiles instead of joint sales-employment profiles. A small firm in terms of employment is not necessarily small in terms of sales (and vice versa). This matters because firms have different growth dynamics when one considers employment or sales as the indicator of firm growth and size.

Conflicts of interest/Competing interests: The authors have no relevant financial or non-financial interests to disclose.

Data Availability Statement: The data that support the findings of this study are available from ICAP Group SA. Restrictions apply to the availability of these data, which were used under license for this study. Data are available at www.icap.gr with the permission of ICAP Group SA.

References

[1] Arkolakis, C., 2016, "A Unified Theory of Firm Selection and Growth", Quarterly Journal of Economics, Vol. 131, No. 1, pp. 89- 155.

[2] Arkolakis, C., T. Papageorgiou and O.A. Timoshenko, 2018, "Firm Growth and Learning", Review of Economic Dynamics, Vol. 27, pp. 146-168.

[3] Bentzen, J., E.S. Madsen and V. Smith, 2012, "Do Firms' Growth Rates Depend on Firm Size?", Small Business Economics, Vol. 39, No. 4, pp. 937–947.

[4] Calvo, J.L., 2006, "Testing Gibrat's Law for Small, Young and Innovating Firms", Small Business Economics, Vol. 26, pp. 117–123.

[5] Chodorow-Reich, G., L. Karabarbounis, and R. Kekre, 2019, "The Macroeconomics of the Greek Depression", National Bureau of Economic Research, NBER Working Paper Series, No. 25900.

[6] Chandler, G.N., A. McKelvie, P. Davidsson, 2009, "Asset Specificity and Behavioural Uncertainty as Moderators of the Sales Growth — Employment Growth Relationship in Emerging Ventures", Journal of Business Venturing, Vol. 24, pp. 373–387.

[7] Coad, A., 2007, "Firm Growth: A Survey", Papers on Economics and Evolution 2007-03, Max Planck Institute of Economics, Evolutionary Economics Group, Jena, Germany.

[8] Coad, A. and W. Hölzl, 2010, "Firm Growth: Empirical Analysis", Handbook on the Economics and Theory of the Firm, Edward Elgar Publishing, pp. 324-338.

[9] Daunfeldt, S.O., and N. Elert, 2013, "When is Gibrat's Law a Law?", Small Business Economics, Vol. 41, No. 1, pp. 133–147.

[10] Davis, S.J., J. Haltiwanger and S. Schuh, 1996, "Small Business and Job Creation: Dissecting the myth and Reassessing the Facts", Small Business Economics, Vol. 8, No.4, pp. 297-315.

[11] Delmar, F., P. Davidsson, and W. Gartner, 2003, "Arriving at the High Growth Firm", Journal of Business Venturing, Vol. 18, No. 2, pp. 189–216.

[12] Dorfman, R., 1938, "A Note on the δ-Method for Finding Variance Formulae", The Biometric Bulletin, Vol. 1, pp. 129-137.

[13] Du, J., and Y. Temouri, 2015, "High-growth firms and productivity: evidence from the United Kingdom", Small Business Economics, Vol. 44, pp. 123–143.

[14] Ericson, R., and A. Pakes, 1995, "Markov-Perfect Industry Dynamics: A Framework for Empirical Work", Review of Economic Studies, Vol. 62, pp. 53–82.

[15] Evans, D. S., 1987, "The Relationship between Firm Growth, Size, and Age: Estimates for 100 Manufacturing Industries", Journal of Industrial Economics, Vol. 35, No. 4, pp. 567-581.

[16] Evans, D., and B. Jovanovic, 1989, "An Estimated Model of Entrepreneurial Choice under Liquidity Constraints", Journal of Political Economy, Vol. 97, No. 4, pp. 808–827.

[17] Fort, T.C., J. Haltiwanger, R.S. Jarmin and J. Miranda, 2013, "How Firms Respond to Business Cycles: The Role of Firm Age and Firm Size", IMF Economic Review, Vol. 61, No. 3, pp 520–559.

[18] Fotopoulos, G., and I. Giotopoulos, 2010, "Gibrat's Law and Persistence of Growth in Greek Manufacturing", Small Business Economics, Vol. 35, pp.191–202.

[19] Gibrat, R., 1931, "Les Inegalites Economiques", Paris: Librairie du Recueil Sirey.

[20] Gourinchas, P.O., T. Philippon and D. Vayanos, 2017, "The Analytics of the Greek Crisis", NBER Macroeconomics Annual, Vol. 31, No. 1, pp. 1–81.

[21] Hall, B. H., 1987, 'The Relationship between Firm Size and Firm Growth in the U.S. Manufacturing Sector", Journal of Industrial Economics, Vol. 35, No. 4, pp. 583-600.

[22] Haltiwanger, J., R.S. Jarmin and J. Miranda, 2013, "Who Creates Jobs? Small Versus Large Versus Young", The Review of Economics and Statistics, Vol. 95, No. 2, pp. 347-361.

[23] Harhoff, D., K. Stahl, M. Woywode, 1998, "Legal Form, Growth and Exits of West German Firms – Empirical Results for Manufacturing, Construction, Trade and Service Industries", Journal of Industrial Economics, Vol. 46, No. 4, pp. 453-488.

[24] Hart, P. E. and N.Oulton, 1996, 'The Growth and Size of Firms"', Economic Journal, Vol. 106, No. 3, pp. 1242-1252.

[25] Heckman, J., 1979, "Sample Selection Bias as a Specification Error", Econometrica, Vol. 47, No. 1, pp. 153–61.

[26] Heshmati, A., 2001, "On the Growth of Micro and Small Firms", Small Business Economics, Vol. 17, pp. 213–218.

[27] Hopenhayn, H, 1992, "Entry, Exit, and Firm Dynamics in Long Run Equilibrium", Econometrica, Vol. 60, No. 5, pp. 1127–1150.

[28] Jovanovic, B., 1982, "Selection and Evolution of Industry", Econometrica, Vol. 50, No. 3, pp. 649-670.

[29] Lopez-Garcia, P., and S. Puente, 2012, "What makes a High-growth Firm in Spain? A Dynamic Probit Analysis using Firm-level Data", Small Business Economics, Vol. 39, No. 2, pp. 1029–1041.

[30] Lotti, F., E.Santarelli, and M. Vivarelli, 2007, “Defending Gibrat’s Law as a Long-run Regularity”, Small Business Economics, Vol. 32, pp. 31–44.

[31] Luttmer, E., 2007, "Selection, Growth, and the Size Distribution of Firms", Quarterly Journal of Economics, Vol. 122, No. 3, pp.1103-1144.

[32] Mansfield, E., 1962, “Entry, Gibrat’s Law, Innovation and the Growth of Firms”, American Economic Review”, Vol. 52, pp. 1023-1051.

[33] Marsili, O., 2001, “The Anatomy and Evolution of Industries”, Edward Elgar: Cheltenham.

[34] Navaretti, G.B., D. Castellani, and F. Pieri, 2014, “Age and Firm Growth: Evidence from three European Countries”, Small Business Economics, Vol. 43, pp. 823–837.

[35] Olley, G.S. and A. Pakes, 1996, “The Dynamics of Productivity in the Telecommunication Equipment Industry”, Econometrica, Vol. 69, No. 2, pp. 307-342.

[36] Sutton, J., 1997, “Gibrat’s Legacy”, Journal of Economic Literature, Vol. 35, pp. 40-59.

[37] Tornqvist, L., P. Vartia, and Y. Vartia, 1985, “How should Relative Changes be Measured?”, The American Statistician, Vol. 39, No. 1, pp. 43-46.

[38] Williams, R., 2012, “Using the Margins Command to Estimate and Interpret Adjusted Predictions and Marginal Effects”, The Stata Journal, Vol. 12, No. 2, pp. 308–331.

[39] Yasuda, T., 2005, “Firm Growth, Size, Age and Behavior in Japanese Manufacturing”, Small Business Economics, Vol. 24, pp. 1-15

Appendices

A Data Cleaning

The firm-level data are proprietary and have been obtained from ICAP Group SA, a private research company that collects detailed balance sheet and income statement data for SA and Ltd companies in Greece, along with their establishment date, location and ownership status, for credit risk evaluation and management consulting. Because the ICAP database is used for credit decisions, the data are carefully controlled. Our dataset contains firm-level information for approximately 80,500 Greek firms operating in all sectors, except for banks and insurance companies, for the time period 1998 - 2014. For this paper we use information on gross sales, gross output/revenue, total balance-sheet assets, long-term liabilities, short-term liabilities, year of establishment, NACE2 codes, firm location and accounting depreciation flow. The aggregate data and deflators for Greece are collected from two publicly available sources: the Eurostat and the Organization for Economic Cooperation and Development.

We prepare the data for estimation in two stages. First, we clean the data from basic reporting mistakes. Second, we trace and deal with gaps in the data.[25] In particular, we implement the following steps to clean the data:

1. We set to missing firm-year observations of gross sales and employment that are negative.
2. We keep firm-year observations that have information on gross sales, employment and establishment date.
3. We audit for duplicates in our data.
4. We deal with potential gaps in the data. Due to the high number of missing observations in our sample, in order to ensure the internal consistency of our dataset, we delete the information either of the firms whose sales or employment data has 4 or more gaps, or of the firms with 2 or 3 gaps if the maximum length of a gap is at least 5 consecutive years.

Finally, we trim the top and bottom 1% of firm sales growth rates to minimize the effect of outliers.

B Allocation of Firms across the Age and Size Distributions

******* Insert Table B1 here *******

[25] By the term gap we mean a set of missing consecutive firm-year observations.

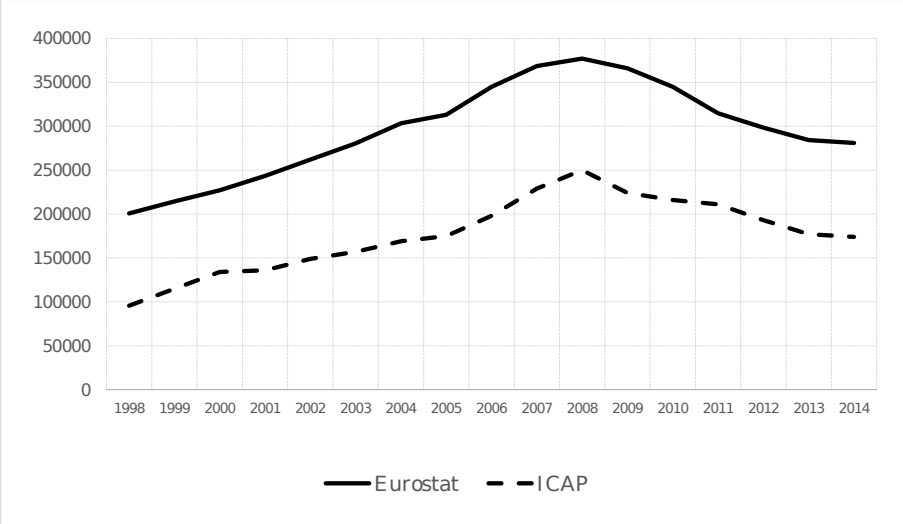
C Estimation Results for Econometric Specification (1)

Table C1 presents the estimation results for the econometric specification (2). Since model (2) consists of categorical variables and especially since these variables are interacted, the regression coefficient estimates do not capture the partial effect of firm age or size on firm growth (Williams, 2012). Therefore, following Haltiwanger et al. (2013), we present marginal effects at means (MEMs) instead of regression coefficients, in order to capture properly the partial effects of both firm age and size on firm growth. MEMs of firm size from model (2) are computed by holding the age distribution of sales (or employment) constant at the sample mean. MEMs of firm age are analogously computed by holding the size distribution of sales (or employment) constant at the sample mean.

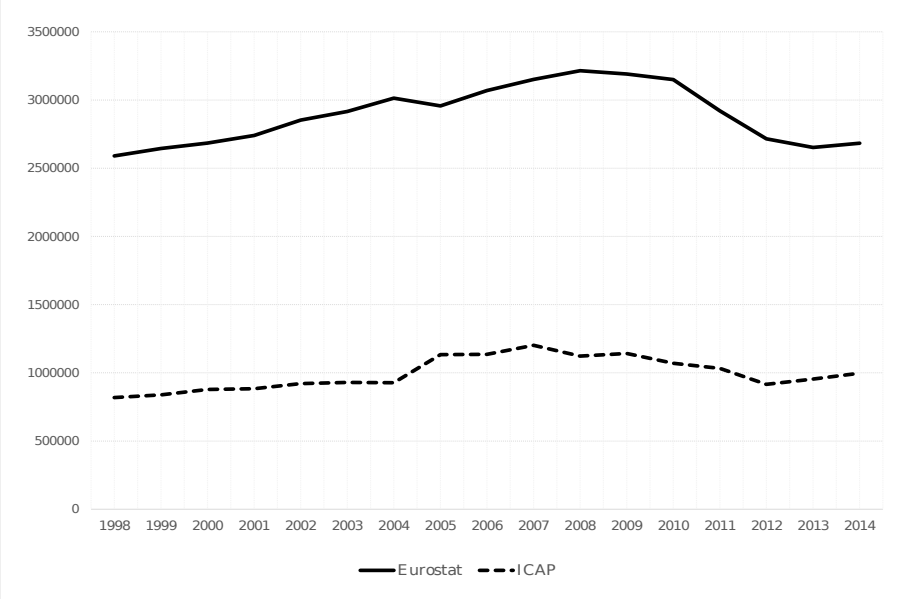
We estimate four alternative versions of model (2), two for firm sales and two for firm employment. First, we calculate growth using the logarithmic difference of deflated sales as a measure of firm sales growth and the base-year definition of firm size (i.e. the logarithm of deflated sales at period $t-1$). We denote this measure as the "traditional" one. Second, we calculate growth employing the Davis et al.'s (1996) definitions for the firm sales growth rates and firm size, defined earlier in subsection 2.2. We denote this as the "DHS" measure. Third, we calculate growth using the "traditional" measure for employment growth and firm size. Finally, we estimate the model (2) for employment using the "DHS" measure for employment growth rates and size.

******* Insert Table C1 here *******

Figures



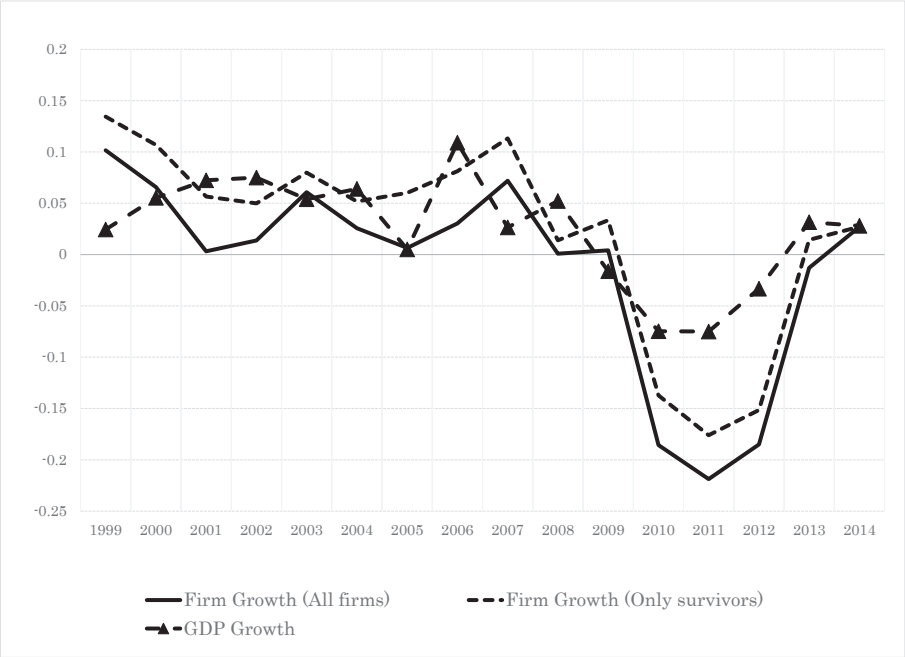
(a) Gross Output



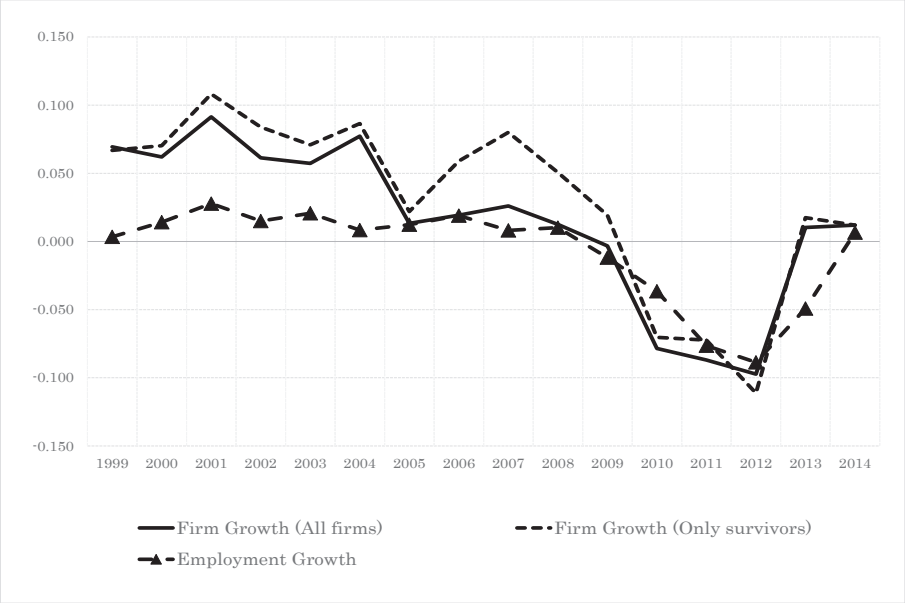
(b) Aggregate Employment

Figure 1: Aggregates in ICAP and Eurostat (SBS)

Notes: In this Figure, we compare the evolution of the aggregate gross output and employment in our ICAP dataset with the same aggregates as recorded by Eurostat (SBS).



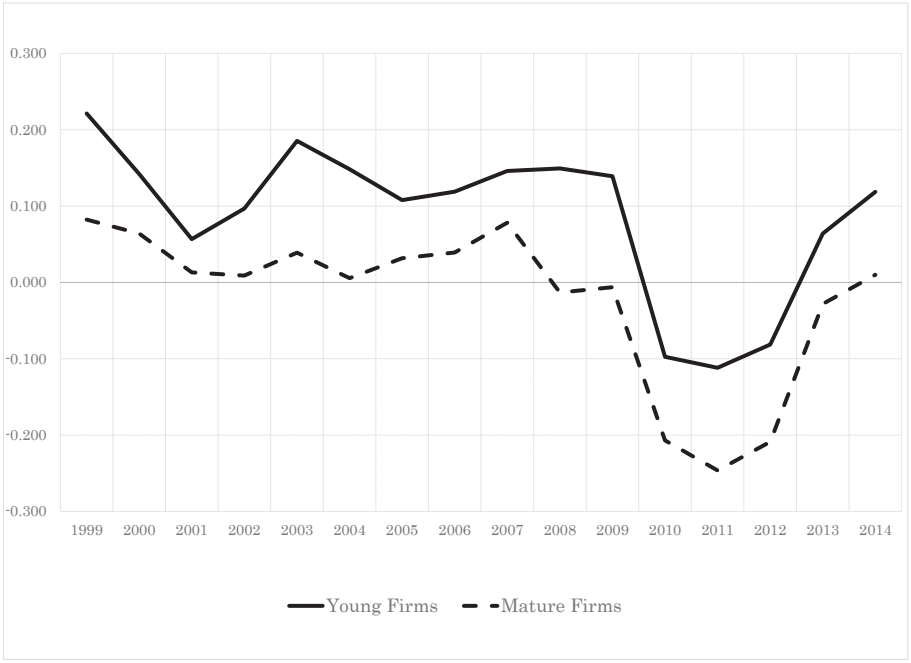
(a) Sales



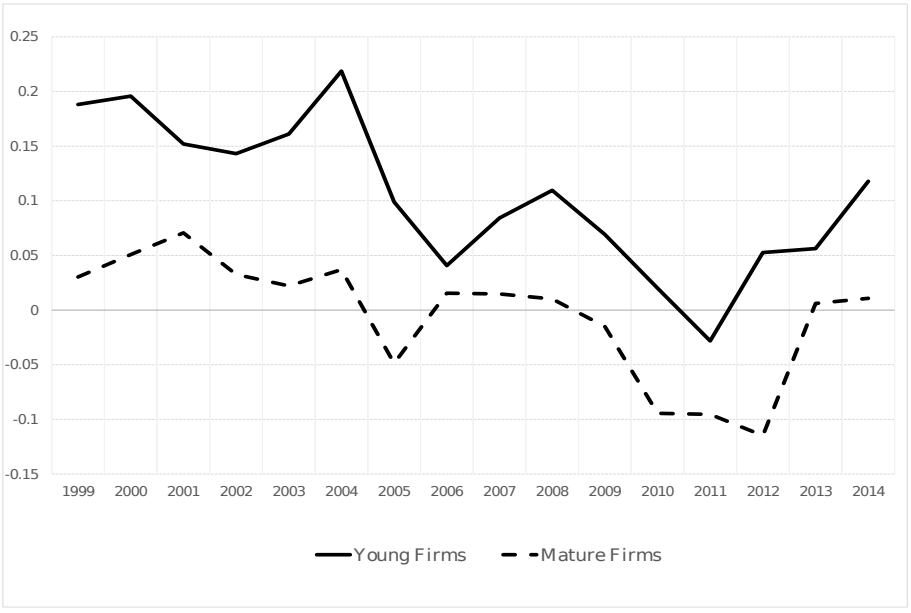
(b) Employment

Figure 2: Dynamic Patterns of Firm Growth

Notes: This figure presents the dynamic patterns of average annual firm growth rates of Greek firms for the time period 1998-2014. Panel (a) displays the patterns of sales growth, whilst Panel (b) the patterns of employment growth. To investigate whether the growth rates of the firm-level data resemble the growth path of the Greek economy, we also include the growth rates of the Gross Domestic Product (GDP hereafter) annual time series in Panel (a) and the growth rates of aggregate employment annual time series in Panel (b), as reported in the OECD Database.



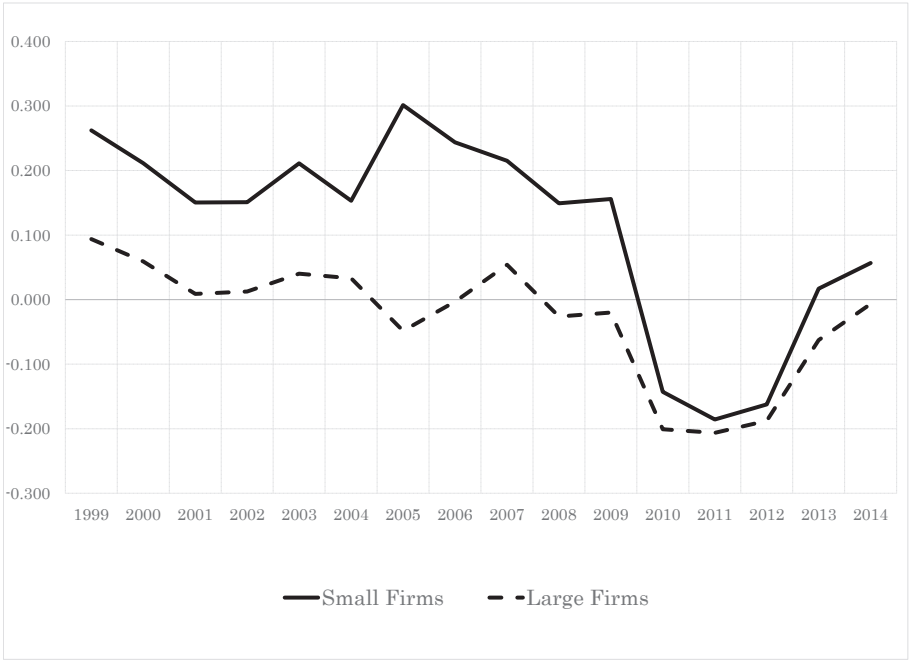
(a) Sales



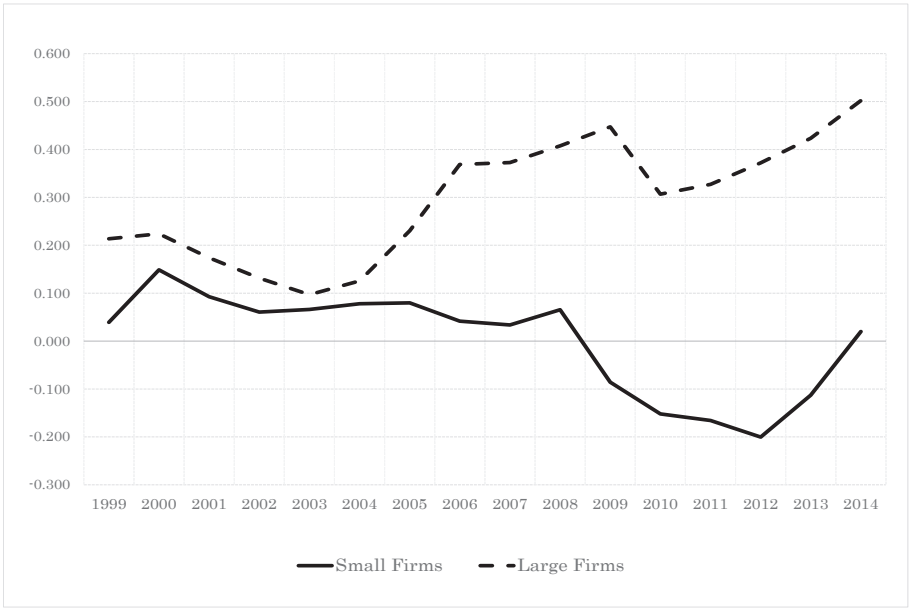
(b) Employment

Figure 3: Firm Growth by Age Group

Notes: In this figure we present the dynamic patterns of firm growth rate by age groups. Panel (a) displays the patterns of sales growth, whilst Panel (b) for employment growth. A firm is defined as "mature" if its age is larger than 5 years and "young" otherwise.



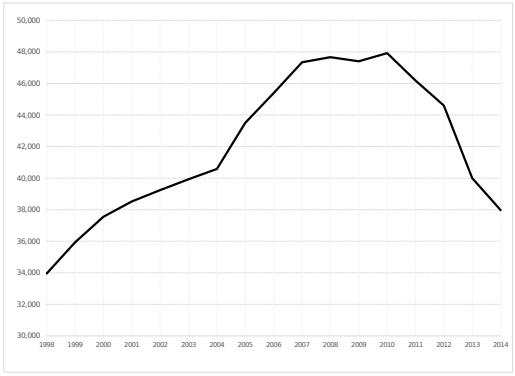
(a) Sales



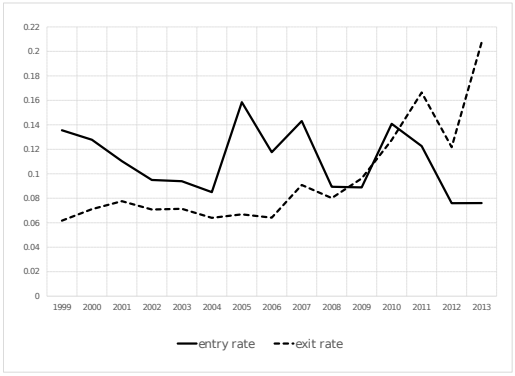
(b) Employment

Figure 4: Firm Growth by Size Group

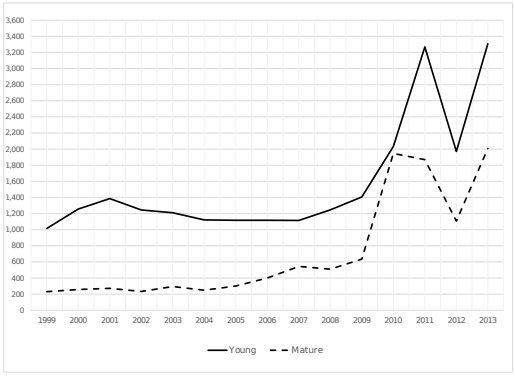
Notes: In this figure we present the dynamic patterns of firm growth rate by size groups. Panel (a) displays the patterns of sales growth, whilst Panel (b) for employment growth. We classify firms into three sales size groups: small for percentiles 1-50 of the sales distribution, medium for percentiles 51-90 and large for the percentiles 91-100. We classify firms into three employment size groups: small for firm with less than 20 employees, medium for firms with 20-49 employees and large for firms with more than 50 employees.



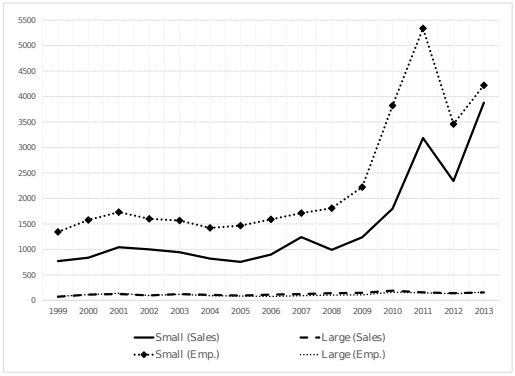
(a) Number of Firms



(b) Entry and Exit



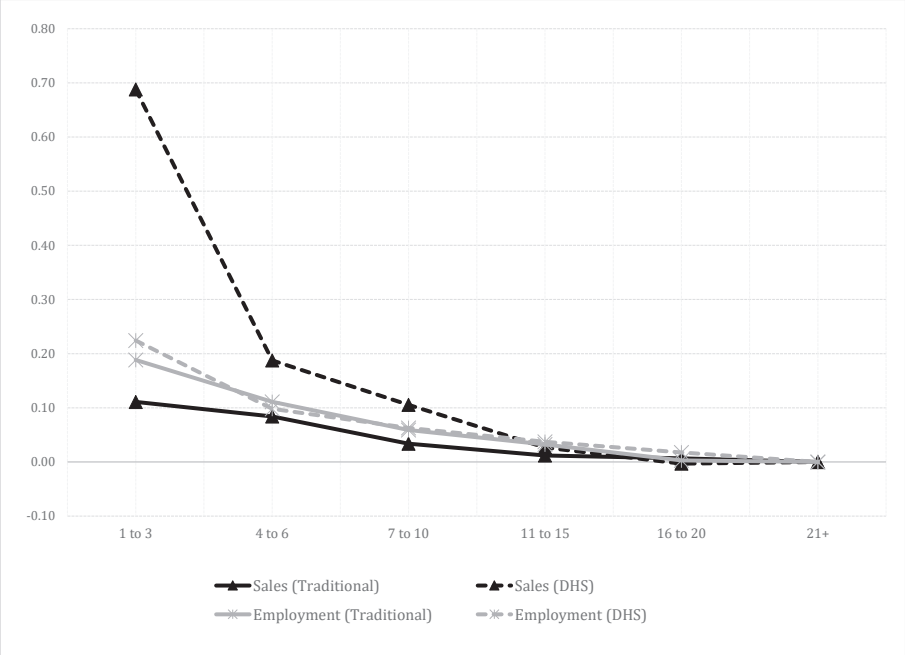
(c) Exit by Firm Age



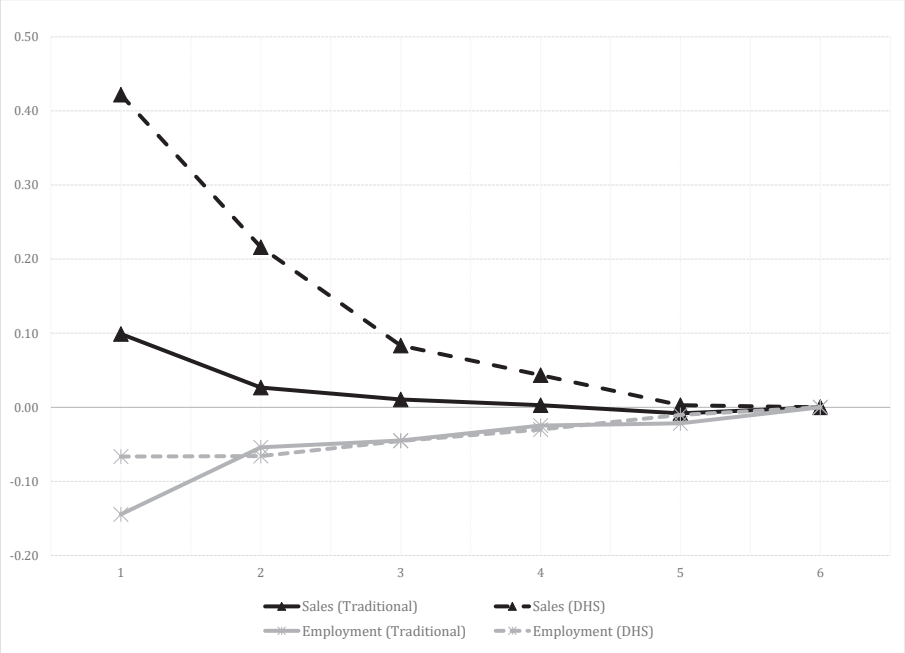
(d) Exit by Firm Size

Figure 5: Entry, Exit and the Number of Firms

Notes: In this figure we present the dynamic patterns of the number of firms, the firm entry, and the firm exit in our sample. Panel (a) depicts the evolution of the number of firms in our dataset, whist Panel (b) illustrates the patterns of firm entry and exit rates in our sample. Panel (c) presents the number of firm exits in our dataset for young and mature firms. A firm is defined as "mature" if its age is greater than 5 years and "young" otherwise. Panel (d) depicts the number of firm exits for small and large firms (we omit the medium-sized firms). Firms are classified into three sales size groups: small for percentiles 1-50 of the sales distribution, medium for percentiles 51-90 and large for the percentiles 91-100. Firms are also classified into three employment size groups: small for firm with less than 20 employees, medium for firms with 20-49 employees and large for firms with more than 50 employees.



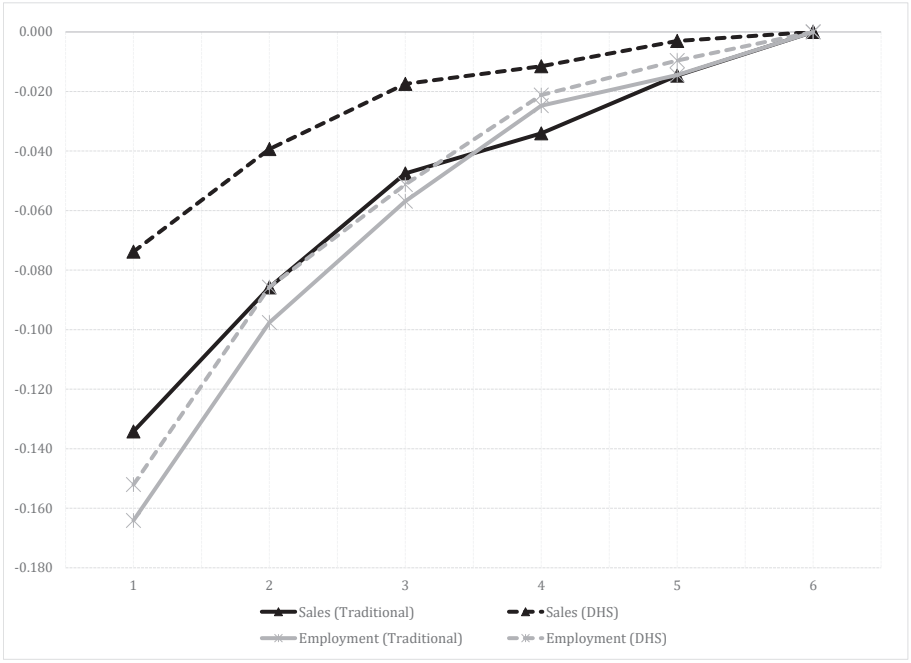
(a) Relationship between Firm Growth and Firm Age



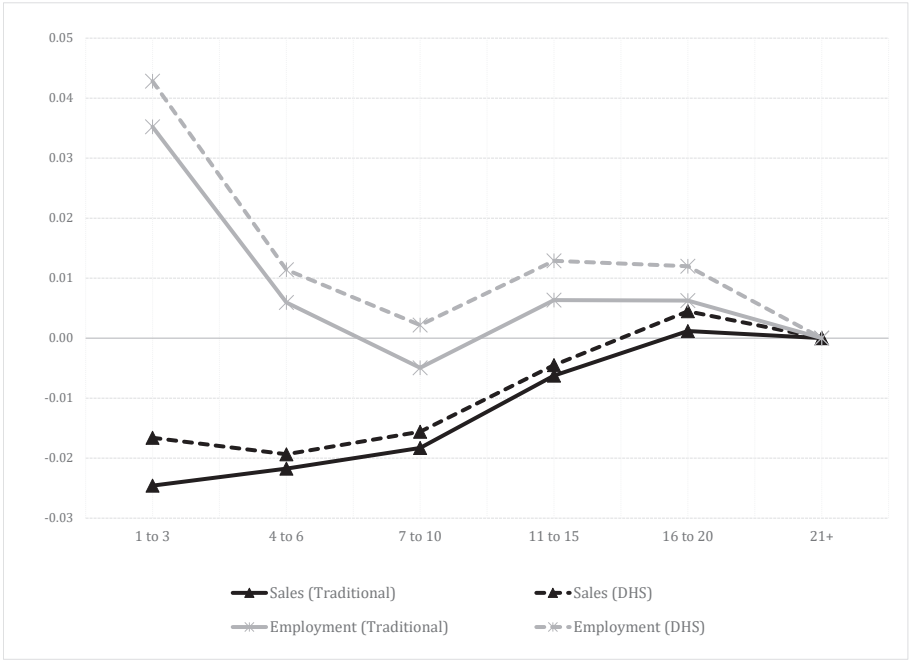
(b) Relationship between Firm Growth and Firm Size

Figure 6: Relationship between Firm Growth and Firm Age and Size

Notes: In this figure, we investigate the role of firm age and firm size in sales and employment firm growth rates of Greek firms during the period 1999-2014. The Figure illustrates the marginal effects at means (MEMs) instead of the regression coefficients since they compute properly the partial effects of age and size. The cited average marginal effects were obtained by the estimation of econometric specification (2). We compute marginal effects of firm size (age) from that model holding the age (size) distribution of sales/employment constant at the sample mean. We estimate four alternative versions of model (2), two for firm sales and two for firm employment. First, we calculate growth using the logarithmic difference of deflated sales as a measure of firm sales growth and the base-year definition of firm size (i.e. the logarithm of deflated sales at period $t-1$). We denote this measure as the "traditional" one. Second, we calculate growth employing the Davis et al.'s (1996) definitions for the firm sales growth rates and firm size, defined earlier in subsection 2.2. We denote this as the "DHS" measure. Third, we calculate growth using the "traditional" measure for employment growth and firm size. Finally, we estimate the model (2) for employment using the "DHS" measure for employment growth rates and size. We categorize firms in six age groups 1-3, 4-6, 7-10, 11-15, 16-20, 20^{+} years and in six size groups for sales 1-30, 31-60, 61-70, 71-80, 81-90, 91-100 percentiles of the sales distribution or for employment 1-4, 5-9, 10-19, 20-49, 50-99, 100^{+} employees. To facilitate comparisons between employment and sales, we focus on comparing the differences in effects relative to a baseline or omitted group. The baseline group for size contains the largest firms whereas for age it contains the oldest firms.



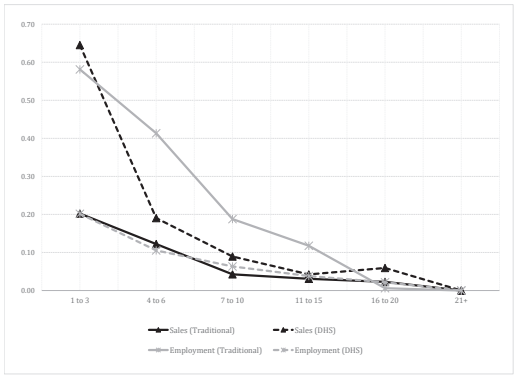
(a) Survival Probability by Firm Size



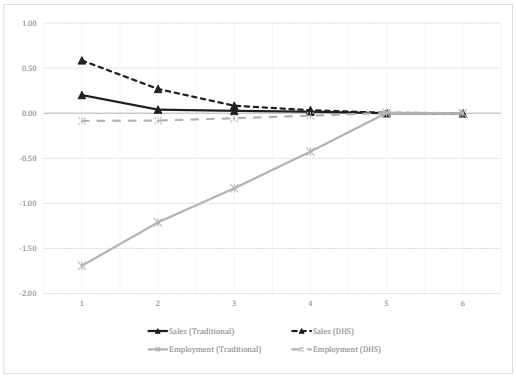
(b) Survival Probability by Firm Age

Figure 7: Relationship between Firm Survival and Firm Age and Size

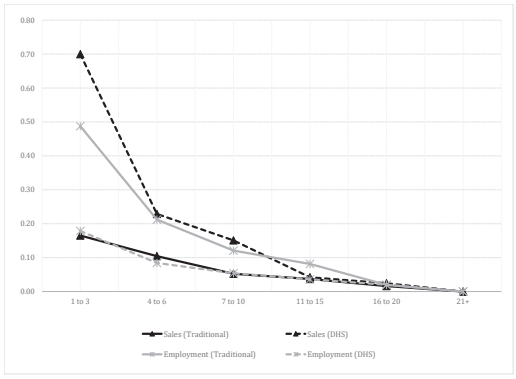
Notes: In this figure, we investigate the role of firm age and firm size in firm survival probabilities of Greek firms during the period 1999-2014. The Figure illustrates the marginal effects at means (MEMs) instead of the regression coefficients since they compute properly the partial effects of age and size. The cited average marginal effects were obtained by the estimation of econometric specification (4). We compute marginal effects of firm size (age) from that model holding the age (size) distribution of sales/employment constant at the sample mean. We estimate four alternative versions of model (4), two for firm sales and two for firm employment. First, we estimate it using the the base-year definition of firm size in terms of sales (we call this type of measurement as "traditional"). Second, we estimated it by employing the Davis et al.'s (1996) definition for firm size in terms of sales (we call this type of measurement as "DHS"). Third, we estimate it using the "traditional" measurement for firm size in terms of employment. Finally, we estimate the model (4) for employment using the "DHS" measurement for the firm size. We categorize firms in six age groups 1-3, 4-6, 7-10, 11-15, 16-20, 20^{+} years and in six size groups for sales 1-30, 31-60, 61-70, 71-80, 81-90, 91-100 percentiles of the sales distribution or for employment 1-4, 5-9, 10-19, 20-49, 50-99, 100^{+} employees. To facilitate comparisons between employment and sales, we focus on comparing the differences in effects relative to a baseline or omitted group. The baseline group for size contains the largest firms whereas for age it contains the oldest firms.



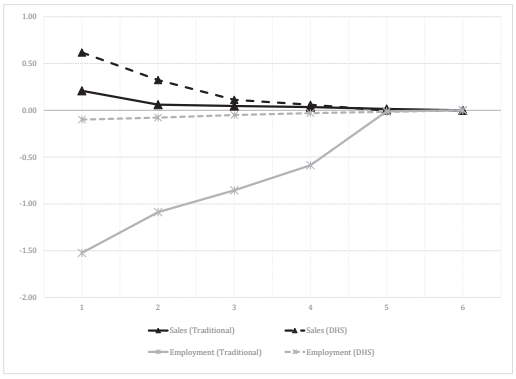
(a) Manufacturing: Growth-Age Relationship



(b) Manufacturing: Growth-Size Relationship



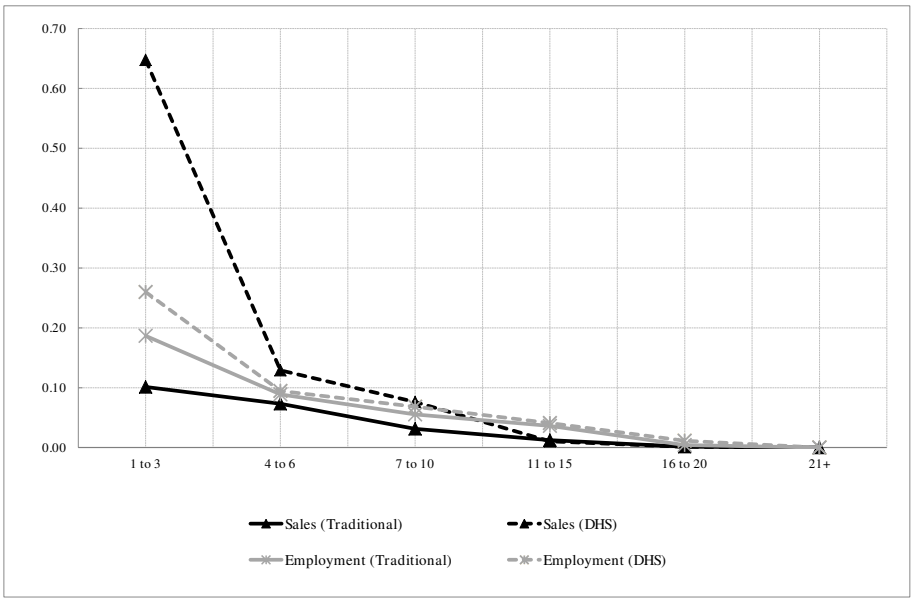
(c) Trade: Growth-Age Relationship



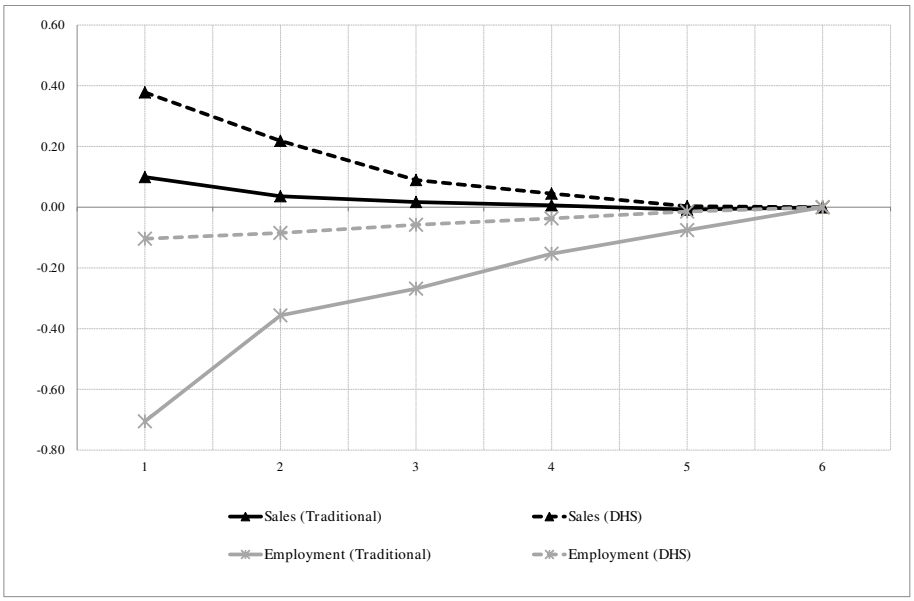
(d) Trade: Growth-Size Relationship

Figure 8: Relationship between Firm Growth and Firm Age and Size in the Greek "Manufacturing" and "Trade, Transportation and Accommodation" Sectors

Notes: In this figure, we investigate the role of firm age and firm size in sales and employment firm growth rates in the "Manufacturing" (Panels (a) and (b)) and "Trade, Transportation and Accommodation" (Panels (c) and (d)) Sectors of the Greek economy during the period 1999-2014. The Figure illustrates the marginal effects at means (MEMs) instead of the regression coefficients since they compute properly the partial effects of age and size. The cited average marginal effects were obtained by the estimation of econometric specification (2). We compute marginal effects of firm size (age) from that model holding the age (size) distribution of sales/employment constant at the sample mean. We estimate four alternative versions of model (2), two for firm sales and two for firm employment. First, we calculate growth using the logarithmic difference of deflated sales as a measure of firm sales growth and the base-year definition of firm size (i.e. the logarithm of deflated sales at period $t-1$). We denote this measure as the "traditional" one. Second, we calculate growth employing the Davis et al.'s (1996) definitions for the firm sales growth rates and firm size, defined earlier in subsection 2.2. We denote this as the "DHS" measure. Third, we calculate growth using the "traditional" measure for employment growth and firm size. Finally, we estimate the model (2) for employment using the "DHS" measure for employment growth rates and size. We categorize firms in six age groups 1-3, 4-6, 7-10, 11-15, 16-20, 20^{+} years and in six size groups for sales 1-30, 31-60, 61-70, 71-80, 81-90, 91-100 percentiles of the sales distribution or for employment 1-4, 5-9, 10-19, 20-49, 50-99, 100^{+} employees. To facilitate comparisons between employment and sales, we focus on comparing the differences in effects relative to a baseline or omitted group. The baseline group for size contains the largest firms whereas for age it contains the oldest firms.



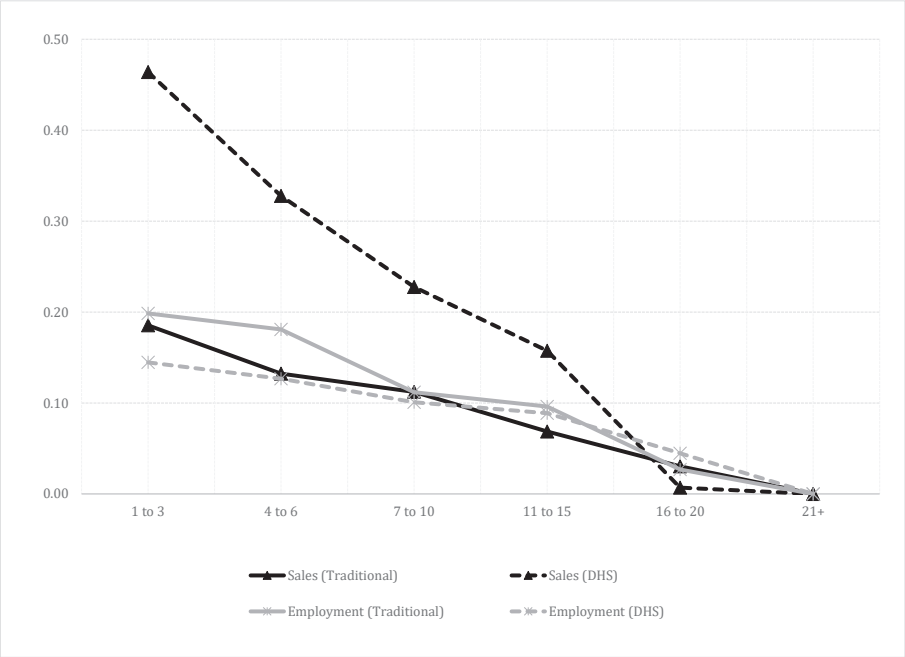
(a) Relationship between Firm Growth and Firm Age



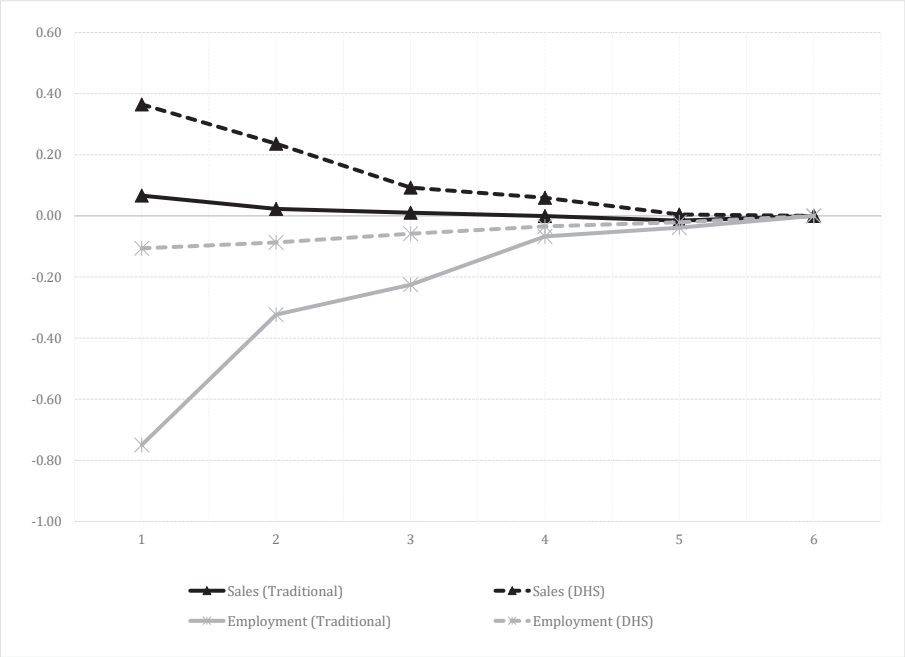
(b) Relationship between Firm Growth and Firm Size

Figure 9: Growth-Age and Growth-Size Relationships, excluding the Crisis Period 2010-2014

Notes: In this figure, we present the estimation results for model (2) restricting the sample in the the pre-crisis period (1999-2009) to examine whether the growth-age and growth-size relationships were (partly) driven by the eruption of the Greek Depression in 2010. The Figure illustrates the marginal effects at means (MEMs) instead of the regression coefficients since they compute properly the partial effects of age and size. We compute marginal effects of firm size (age) from that model holding the age (size) distribution of sales/employment constant at the sample mean. We estimate four alternative versions of model (2), two for firm sales and two for firm employment. First, we calculate growth using the logarithmic difference of deflated sales as a measure of firm sales growth and the base-year definition of firm size (i.e. the logarithm of deflated sales at period $t-1$). We denote this measure as the "traditional" one. Second, we calculate growth employing the Davis et al.'s (1996) definitions for the firm sales growth rates and firm size, defined earlier in subsection 2.2. We denote this as the "DHS" measure. Third, we calculate growth using the "traditional" measure for employment growth and firm size. Finally, we estimate the model (2) for employment using the "DHS" measure for employment growth rates and size. We categorize firms in six age groups 1-3, 4-6, 7-10, 11-15, 16-20, 20^{+} years and in six size groups for sales 1-30, 31-60, 61-70, 71-80, 81-90, 91-100 percentiles of the sales distribution or for employment 1-4, 5-9, 10-19, 20-49, 50-99, 100^{+} employees. To facilitate comparisons between employment and sales, we focus on comparing the differences in effects relative to a baseline or omitted group. The baseline group for size contains the largest firms whereas for age it contains the oldest firms.



(a) Relationship between Firm Growth and Firm Age



(b) Relationship between Firm Growth and Firm Size

Figure 10: Growth-Age and Growth-Size Relationships using Heckman's (1979) Method for Sampling Bias Correction

Notes: In this figure, we present the estimation results for model (2) using the Heckman's (1979) method for correcting the sampling bias. The Figure illustrates the marginal effects at means (MEMs) instead of the regression coefficients since they compute properly the partial effects of age and size. We compute marginal effects of firm size (age) from that model holding the age (size) distribution of sales/employment constant at the sample mean. We estimate four alternative versions of model (2), two for firm sales and two for firm employment. First, we calculate growth using the logarithmic difference of deflated sales as a measure of firm sales growth and the base-year definition of firm size (i.e. the logarithm of deflated sales at period $t-1$). We denote this measure as the "traditional" one. Second, we calculate growth employing the Davis et al.'s (1996) definitions for the firm sales growth rates and firm size, defined earlier in subsection 2.2. We denote this as the "DHS" measure. Third, we calculate growth using the "traditional" measure for employment growth and firm size. Finally, we estimate the model (2) for employment using the "DHS" measure for employment growth rates and size. We categorize firms in six age groups 1-3, 4-6, 7-10, 11-15, 16-20, 20^{+} years and in six size groups for sales 1-30, 31-60, 61-70, 71-80, 81-90, 91-100 percentiles of the sales distribution or for employment 1-4, 5-9, 10-19, 20-49, 50-99, 100^{+} employees. To facilitate comparisons between employment and sales, we focus on comparing the differences in effects relative to a baseline or omitted group. The baseline group for size contains the largest firms whereas for age it contains the oldest firms.

Tables

Year	Gross Output	Employment
1998	0.48	0.32
1999	0.54	0.32
2000	0.59	0.33
2001	0.56	0.32
2002	0.57	0.32
2003	0.56	0.32
2004	0.56	0.31
2005	056	0.38
2006	0.57	0.37
2007	0.62	0.38
2008	0.66	0.35
2009	0.61	0.36
2010	0.63	0.34
2011	0.67	0.35
2012	0.65	0.34
2013	0.62	0.36
2014	0.62	0.37
Average	0.60	0.34

Notes: This Table summarizes the coverage in our data for Greece between 1998 and 2014. The columns in the table represent the ratio of aggregate gross output and employment recorded in our sample relative to the same object in Eurostat as reported by its Structural Business Statistics (SBS). At the firm-level, gross output was measured by aggregate gross sales, deflated by the Producer Price Index (PPI).

Table 1: Coverage in ICAP Relative to Eurostat

Sector (two-digit NACE Rev. 2)	Gross Output		Employment	
	Coverage	Share	Coverage	Share
Agriculture, forestry and fishing	0.11	0.04	0.08	0.04
Manufacturing	0.82	0.18	0.71	0.12
Wholesale and retail trade, transport, accommodation and food service activities	0.79	0.28	0.42	0.34
Industry	0.68	0.04	0.08	0.14
Construction	0.22	0.09	0.17	0.07
Information and communication	0.84	0.04	0.71	0.03
Financial and insurance activities	0.68	0.04	0.97	0.03
Real estate activities	0.05	0.08	1.00	0.00
Professional, scientific and technical activities	0.26	0.04	0.16	0.06
Services	0.16	0.20	0.07	0.36
Overall Economy	0.60	1.00	0.34	1.00

Notes: This Table summarizes the average coverage in our data for Greece by sector over the period 1998 and 2014, along with the share of each sector in the aggreate gross output and employment. Sectors have been classified according to their two-digit NACE Rev. 2 codes. Coverage denotes the ratio of aggregate gross output and employment recorded in our sample relative to the same object in Eurostat as reported by its Structural Business Statistics (SBS). At the firm-level, gross output was measured by aggregate gross sales, deflated by the Producer Price Index (PPI).

Table 2: Coverage in ICAP Relative to Eurostat by Sector

	Employment			
Sales	Small	Medium	Large	**Total**
Small	69.5	29.0	1.5	100.00
Medium	26.0	61.5	12.5	100.00
Large	6.5	31.5	62.0	100.00
Total	0.50	0.40	0.10	100.00
	Sales			
Employment	Small	Medium	Large	**Total**
Small	73.5	25.0	1.5	100.00
Medium	31.0	61.0	8.0	100.00
Large	5.5	42.0	52.5	100.00
Total	0.50	0.40	0.10	100.00

Notes: This Table reports the portions of firms by sales and employment size groups. The cross-tabulation is based on the base-year definition of firm size for both sales and employment. However, the average size definition of Davis et al. (1996) leads to almost identical results.We classify firms into three sales (employment) size groups: small for percentiles 1-50 of the sales (employment) distribution at period $t-1$, medium for percentiles 51-90 and large for percentiles 91-100.

Table 3: Cross Tabulation - Sales VS Employment Size Groups

	Employment						
Sales	1-4 employees	5-9 employees	10-19 employees	20-49 employees	50-99 employees	100^{+} employees	**Total**
1-30 percentiles	75.08	14.42	7.28	2.39	0.47	0.36	100.00
31-60 percentiles	42.88	25.57	21.50	8.66	0.91	0.49	100.00
61-70 percentiles	23.69	23.67	29.01	20.46	2.29	0.88	100.00
72-80 percentiles	16.87	18.77	29.19	28.58	5.22	1.36	100.00
81-90 percentiles	10.88	11.48	23.80	36.54	13.09	4.21	100.00
91-100 percentiles	5.51	4.55	10.31	26.55	21.14	31.94	100.00
Total	39.22	17.90	18.36	15.26	4.88	4.38	100.00

	Sales						
Employment	1-30 percentiles (€ 337,931)	31-60 percentiles (€ 1,330,783)	61-70 percentiles (€ 2,062,252)	72-80 percentiles (€ 3,479,652)	81-90 percentiles (€ 7,638,714)	91-100 percentiles	**Total**
1-4 employees	51.00	33.58	6.38	4.57	2.96	1.52	100.00
5-9 employees	21.46	43.86	13.97	11.13	6.83	2.75	100.00
10-19 employees	10.56	35.97	16.69	16.89	13.82	6.07	100.00
20-49 employees	4.17	17.44	14.16	19.90	25.53	18.80	100.00
50-99 employees	2.59	5.73	4.95	11.36	28.58	46.79	100.00
100^{+} employees	2.19	3.41	2.12	3.29	10.25	78.73	100.00
Total	26.64	30.72	10.56	10.62	10.66	10.80	100.00

Notes: This Table reports the portions of firms by sales and employment size groups. The cross-tabulation is based on the base-year definition of firm size for both sales and employment. However, the average size definition of Davis et al. (1996) leads to almost identical results. For the sales-size groups we display the cut-off points (maximum values) of the sales distribution in parentheses.

Table B1: Cross Tabulation - Sales VS Employment Size Groups

	Sales		Employment	
	Traditional	**DHS**	**Traditional**	**DHS**
Age Class				
1 to 3 years	0.037***	0.766***	0.233***	0.201***
	(0.004)	(0.003)	(0.005)	(0.004)
4 to 6 years	0.010***	0.265***	0.155***	0.075***
	(0.000)	(0.003)	(0.004)	(0.002)
7 to 10 years	-0.040***	0.183***	0.103***	0.039***
	(0.002)	(0.003)	(0.003)	(0.002)
11 to 15 years	-0.062***	0.105***	0.077***	0.014***
	(0.002)	(0.003)	(0.003)	(0.001)
16 to 20 years	-0.067***	0.075***	0.047***	-0.006***
	(0.002)	(0.003)	(0.003)	(0.002)
21^{+} years	-0.074***	0.078***	0.044***	-0.024***
	(0.001)	(0.002)	(0.003)	(0.001)
Size Class				
1 to 30 sales percentiles	0.022***	0.452***	-0.221***	0.008***
or 1-4 employees	(0.002)	(0.006)	(0.003)	(0.002)
31 to 60 sales percentiles	-0.050***	0.247***	0.079***	0.009***
or 5-9 employees	(0.001)	(0.005)	(0.003)	(0.001)
61 to 70 sales percentiles	-0.066***	0.114***	0.178***	0.029***
or 10-19 employees	(0.002)	(0.006)	(0.003)	(0.001)
71 to 80 sales percentiles	-0.074***	0.074***	0.291***	0.045***
or 20-49 employees	(0.002)	(0.006)	(0.004)	(0.001)
81 to 90 sales percentiles	-0.085***	0.033***	0.381***	0.065***
or 50-99 employees	(0.002)	(0.006)	(0.009)	(0.003)
91 to 100 sales percentiles	-0.077***	0.030***	0.452***	0.075***
or 100^{+} employees	(0.002)	(0.006)	(0.011)	(0.003)
Observations	404,001	445,624	404,001	445,624

Notes: This Table reports the estimation results for model (2). The Table cites the marginal effects at means (MEMs) instead of the regression coefficients since they compute properly the partial effects of age and size. We compute marginal effects of firm size (age) from that model holding the age (size) distribution of sales/employment constant at the sample mean. We estimate four alternative versions of model (2), two for firm sales and two for firm employment. First, we calculate growth using the logarithmic difference of deflated sales as a measure of firm sales growth and the base-year definition of firm size (i.e. the logarithm of deflated sales at period $t-1$). We denote this measure as the "traditional" one. Second, we calculate growth employing the Davis et al.'s (1996) definitions for the firm sales growth rates and firm size, defined earlier in subsection 2.2. We denote this as the "DHS" measure. Third, we calculate growth using the "traditional" measure for employment growth and firm size. Finally, we estimate the model (2) for employment using the "DHS" measure for employment growth rates and size. Age categories are defined in years, whilst size categories are defined in percentiles of the sales distribution or in number of employees. *, **, *** denote statistical significance at the 10, 5 and 1 percent level respectively. Standard errors are in parentheses. Standard errors are clustered by firm and calculated according to Delta Method (Dorfman, 1938).

Table C1: Marginal Effects at Means of Age and Size on Firm Growth from Model (2)

	Sales		Employment	
	Traditional	**DHS**	**Traditional**	**DHS**
Age Class				
1 to 3 years	0.111***	0.688***	0.188***	0.224***
	(0.004)	(0.004)	(0.006)	(0.004)
4 to 6 years	0.084***	0.187***	0.111***	0.098***
	(0.003)	(0.004)	(0.005)	(0.003)
7 to 10 years	0.034***	0.105***	0.059***	0.063***
	(0.002)	(0.004)	(0.004)	(0.002)
11 to 15 years	0.012***	0.027***	0.032***	0.037***
	(0.002)	(0.003)	(0.004)	(0.002)
16 to 20 years	0.007***	-0.003	0.003	0.018***
	(0.002)	(0.004)	(0.004)	(0.002)
21^{+} years	0.000	0.000	0.000	0.000
	(-)	(-)	(-)	(-)
Size Class				
1 to 30 sales percentiles	0.099***	0.422***	-0.673***	-0.066***
or 1-4 employees	(0.003)	(0.004)	(0.011)	(0.003)
31 to 60 sales percentiles	0.027***	0.216***	-0.374***	-0.066***
or 5-9 employees	(0.003)	(0.003)	(0.011)	(0.003)
61 to 70 sales percentiles	0.011***	0.083***	-0.274***	-0.045***
or 10-19 employees	(0.003)	(0.004)	(0.011)	(0.003)
71 to 80 sales percentiles	0.003	0.044***	-0.162***	-0.030***
or 20-49 employees	(0.003)	(0.004)	(0.011)	(0.003)
81 to 90 sales percentiles	-0.008**	0.003	-0.072***	-0.010**
or 50-99 employees	(0.003)	(0.004)	(0.014)	(0.004)
91 to 100 sales percentiles	0.000	0.000	0.000	0.000
or 100^{+} employees	(-)	(-)	(-)	(-)
Observations	404,001	445,624	404,001	445,624

Notes: This table presents the differential effects of firm age and size on employment and sales growth, depicted in figure (6). We compute these effects as the differences in the marginal effects at means (MEMs), produced by the estimation of the growth model (2), relative to a baseline or omitted group. The baseline group for size contains the largest firms whereas for age it contains the oldest firms. We estimate four alternative versions of model (2), two for firm sales and two for firm employment. First, we calculate growth using the logarithmic difference of deflated sales as a measure of firm sales growth and the base-year definition of firm size (i.e. the logarithm of deflated sales at period $t-1$). We denote this measure as the "traditional" one. Second, we calculate growth employing the Davis et al.'s (1996) definitions for the firm sales growth rates and firm size, defined earlier in subsection 2.2. We denote this as the "DHS" measure. Third, we calculate growth using the "traditional" measure for employment growth and firm size. Finally, we estimate the model (2) for employment using the "DHS" measure for employment growth rates and size. Age categories are defined in years, whilst size categories are defined in percentiles of the sales distribution or in number of employees. *, **, *** denote statistical significance at the 10, 5 and 1 percent level respectively. Standard errors are in parentheses. Standard errors are clustered by firm and calculated according to Delta Method (Dorfman, 1938).

Table C2: Differential Effects of Age and Size on Firm Growth from Model (2)

	Sales		Employment	
	Traditional	**DHS**	**Traditional**	**DHS**
Age Class				
1 to 3 years	-0.025***	-0.017***	0.035***	0.043***
	(0.002)	(0.001)	(0.003)	(0.003)
4 to 6 years	-0.022***	-0.019***	0.006**	0.011***
	(0.002)	(0.001)	(0.003)	(0.003)
7 to 10 years	-0.018***	-0.016***	-0.005*	0.002
	(0.002)	(0.001)	(0.003)	(0.003)
11 to 15 years	-0.006***	-0.004***	0.006**	0.013***
	(0.002)	(0.001)	(0.003)	(0.003)
16 to 20 years	0.001	0.004***	0.006**	0.012***
	(0.002)	(0.001)	(0.003)	(0.003)
21^{+} years	0.000	0.000	0.000	0.000
	(-)	(-)	(-)	(-)
Size Class				
1 to 30 sales percentiles	-0.025***	-0.074***	-0.164***	-0.152***
or 1-4 employees	(0.002)	(0.001)	(0.004)	(0.004)
31 to 60 sales percentiles	-0.022***	-0.039***	-0.098***	-0.086***
or 5-9 employees	(0.002)	(0.001)	(0.004)	(0.004)
61 to 70 sales percentiles	-0.018***	-0.017***	-0.057***	-0.051***
or 10-19 employees	(0.003)	(0.002)	(0.004)	(0.004)
71 to 80 sales percentiles	-0.006**	-0.012***	-0.025***	-0.021***
or 20-49 employees	(0.003)	(0.002)	(0.004)	(0.004)
81 to 90 sales percentiles	0.001	-0.003*	-0.014***	-0.010**
or 50-99 employees	(0.002)	(0.002)	(0.005)	(0.005)
91 to 100 sales percentiles	0.000	0.000	0.000	0.000
or 100^{+} employees	(-)	(-)	(-)	(-)
Observations	404,001	445,624	404,001	445,624

Notes: This table presents the differential effects of firm age and size on firm survival, depicted in figure (7). We compute these effects as the differences in the marginal effects at means (MEMs), produced by the estimation of the growth model (4), relative to a baseline or omitted group. The baseline group for size contains the largest firms whereas for age it contains the oldest firms. We estimate four alternative versions of model (4), two for firm sales and two for firm employment. First, we estimate it using the the base-year definition of firm size in terms of sales (we call this type of measurement as "traditional"). Second, we estimated it by employing the Davis et al.'s (1996) definition for firm size in terms of sales (we call this type of measurement as "DHS"). Third, we estimate it using the "traditional" measurement for firm size in terms of employment. Finally, we estimate the model (4) for employment using the "DHS" measurement for the firm size. Age categories are defined in years, whilst size categories are defined in percentiles of the sales distribution or in number of employees. *, **, *** denote statistical significance at the 10, 5 and 1 percent level respectively. Standard errors are in parentheses. Standard errors are clustered by firm and calculated according to Delta Method (Dorfman, 1938).

Table C3: Differential Effects of Age and Size on Firm Survival from Model (4)

ΟΙΚΟΝΟΜΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

ΣΧΟΛΗ ΟΙΚΟΝΟΜΙΚΩΝ ΕΠΙΣΤΗΜΩΝ
SCHOOL OF ECONOMIC SCIENCES

ΤΜΗΜΑ ΟΙΚΟΝΟΜΙΚΗΣ ΕΠΙΣΤΗΜΗΣ
DEPARTMENT OF ECONOMICS

Department of Economics
Athens University of Economics and Business

List of Recent Working Papers

2020

01-20 Incubated Early Stage Startuppers in Athens and their Initiatives during the Crisis (2010-2016), Ioannis Besis and Ioanna Sapfo Pepelasis

02-20 Alternative Monetary Policy Rules in an Imperfectly Competitive Dynamic Stochastic General Equilibrium Model, George Alogoskoufis and Stelios Giannoulakis

03-20 Quantifying Qualitative Survey Data: New Insights on the (Ir)Rationality of Firms' Forecasts, Alexandros Botsis, Christoph Görtz and Plutarchos Sakellaris

04-20 Can Country-Specific Interest Rate Factors Explain the Forward Premium Anomaly?, Efthymios Argyropoulos, Nikolaos Elias, Dimitris Smyrnakis and Elias Tzavalis

05-20 Signaling product quality through prices in an oligopoly model with costly consumer search, Minghua Cheny, Konstantinos Serfes and Eleftherios Zacharias

06-20 Thinking ahead of the next big crash: Clues from Athens in classical times, George C. Bitros

07-20 Financial crises, firm-level shocks, and large downturns: Evidence from Greece, Stelios Giannoulakis and Plutarchos Sakellaris

08-20 Notes on the Demand Side Secular Stagnation, George D. Demopoulos and Nicholas A. Yannacopoulos

09-20 Institutions and Macroeconomic Performance: Core vs Periphery Countries in the Eurozone, Tryfonas Christou, Apostolis Philippopoulos and Vanghelis Vassilatos

10-20 Macroeconomic Policy Lessons for Greece, George Economides, Dimitris Papageorgiou and Apostolis Philippopoulos

11-20 Energy Transitions and the role of the EU ETS: The case of Greece, Andriana Vlachou and Georgios Pantelias

12-20 Measuring the Default Risk of Small Business Loans: Improved Credit Risk Prediction using Deep Learning, Yiannis Dendramis, Elias Tzavalis and Aikaterini Cheimarioti

14-20 Saving Democracy by Switching to Corporate-like Governance, George C. Bitros

15-20 The impact of the lockdown on the Greek economy and the role of the Recovery Fund, George Economides, Apostolis Philippopoulos and Vanghelis Vassilatos

2021

01-21 Historical Cycles of the Economy of Modern Greece From 1821 to the Present, George Alogoskoufis

02-21 Greece Before and After the Euro: Macroeconomics, Politics and the Quest for Reforms, George Alogoskoufis

03-21 Commodity money and the price level, George C. Bitros

04-21 Destabilizing asymmetries in central banking: With some enlightenment from money in classical Athens, George C. Bitros

05-21 Exploring the Long-Term Impact of Maximum Markup Deregulation, Athanasios Dimas and Christos Genakos

06-21 A regularization approach for estimation and variable selection in high dimensional regression models, Y. Dendramis, L. Giraitis, G. Kapetanios

07-21 Tax Competition in the Presence of Environmental Spillovers, Fabio Antoniou, Panos Hatzipanayotou, Michael S. Michael, Nikos Tsakiris

ΟΙΚΟΝΟΜΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

ΣΧΟΛΗ ΟΙΚΟΝΟΜΙΚΩΝ ΕΠΙΣΤΗΜΩΝ
SCHOOL OF ECONOMIC SCIENCES

ΤΜΗΜΑ ΟΙΚΟΝΟΜΙΚΗΣ ΕΠΙΣΤΗΜΗΣ
DEPARTMENT OF ECONOMICS

Department of Economics
Athens University of Economics and Business

The Department is the oldest Department of Economics in Greece with a pioneering role in organising postgraduate studies in Economics since 1978. Its priority has always been to bring together highly qualified academics and top quality students. Faculty members specialize in a wide range of topics in economics, with teaching and research experience in world-class universities and publications in top academic journals.

The Department constantly strives to maintain its high level of research and teaching standards. It covers a wide range of economic studies in micro-and macroeconomic analysis, banking and finance, public and monetary economics, international and rural economics, labour economics, industrial organization and strategy, economics of the environment and natural resources, economic history and relevant quantitative tools of mathematics, statistics and econometrics.

Its undergraduate program attracts high quality students who, after successful completion of their studies, have excellent prospects for employment in the private and public sector, including areas such as business, banking, finance and advisory services. Also, graduates of the program have solid foundations in economics and related tools and are regularly admitted to top graduate programs internationally. Three specializations are offered:1. Economic Theory and Policy, 2. Business Economics and Finance and 3. International and European Economics. The postgraduate programs of the Department (M.Sc and Ph.D) are highly regarded and attract a large number of quality candidates every year.

For more information:

https://www.dept.aueb.gr/en/econ/