Hacettepe University Graduate School of Social Sciences

Department of Economics

R&D VOLATILITY AND FIRM GROWTH: THE CASE OF MANUFACTURING FIRMS IN TURKEY

Ebru Burcu YARDIMCI

Master’s Thesis

Ankara, 2021

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ABSTRACT

YARDIMCI, Ebru Burcu. R&D Volatility and Firm Growth: The Case of Manufacturing Firms in Turkey, Master's Thesis, Ankara 2021.

The aim of this study is to investigate the impact of R&D volatility on firm growth in the Turkish manufacturing industry. Our empirical analysis covers the period 2006-2015 and relies on "The R&D Activities Survey in Business Enterprises Sector Micro Dataset" collected from TURKSTAT. As R&D and non-R&D firms are not randomly selected in our dataset, to overcome the possible selection problem we use Heckman's two-stage procedure for sample selection. Our results show that R&D volatility which is an indicator of proactive R&D management significantly improves the performance of the firm growth with more pronounced effects at the upper end of the size distribution. Tangible and intangible asset volatility has been observed as a complementary element regarding this positive relationship between R&D volatility and growth, particularly for larger firms.

Keywords

R&D, Volatility, Firm Growth, Proactive R&D Management

ÖZET

YARDIMCI, Ebru Burcu. Ar-Ge Volatilitesi ve Firma Büyümesi: Türkiye'de İmalat Firmaları Örneği, Yüksek Lisans Tezi, Ankara 2021.

Bu çalışmanın amacı, Türkiye imalat sanayi için Ar-Ge volatilitesinin firma büyümesi üzerindeki etkisini araştırmaktır. Ampirik analiz, 2006-2015 dönemini kapsayan ve TÜİK 'ten elde edilen “Ticari İşletmeler Sektörü Mikro Veri Setinde Ar-Ge Faaliyetleri Anketi” ne dayanmaktadır. Veri setinde Ar-Ge yapan ve Ar-Ge yapmayan firmalar rastgele seçilemediğinden, olası örneklem seçim probleminin üstesinden gelebilmek amacıyla Heckman’ın iki aşamalı tahmin yöntemi kullanılmıştır. Sonuçlar, proaktif Ar-Ge yönetiminin bir göstergesi olan Ar-Ge volatilitesinin, büyüklük dağılımının üst ucunda daha belirgin etkilerle firma büyüme performansını iyileştirdiğini göstermektedir. Ar-Ge volatilitesi ile büyüme arasındaki bu pozitif ilişkide, maddi ve maddi olmayan duran varlık volatilitesinin, özellikle büyük firmalar için tamamlayıcı bir unsur olduğu gözlemlenmiştir.

Anahtar Kelimeler

Ar-Ge, Volatilite, Firma Büyümesi, Proaktif Ar-Ge Yönetimi

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INTRODUCTION

According to the definition of OECD, R&D means innovative work carried out systematically to increase the knowledge base and use this knowledge to create new applications.[1] R&D activities have a major role in the economic development and prosperity of a country by dealing with the global challenges regarding its production capacity. Notwithstanding, it should not be forgotten that firms are the decision-making units of an economy that are directly occupied in R&D. While the R&D capacity of firms specifies their competitive power, it plays an important role in their growth performance as an effective tool for achieving innovation.

The related literature agrees that the R&D activity of a firm is an important component of its knowledge accumulation process ensuring comparative advantage for firms via transforming that knowledge to firm value and firm growth (Aghion et al., 2005). The majority of the studies concentrate on the R&D level of firms where increasing R&D expenditure is expected to have beneficial consequences. Considering simply the quantitative differences in R&D expenditure of firms, on the other hand, may lead researchers and policymakers to wrong assessments. Namely, understanding the heterogeneity of firms in terms of their R&D routines is critical for comprehending the differences in their growth performance (Nelson and Winter, 1982; Dosi et al., 2010). Particularly, considering the volatility and persistence of the R&D operations of firms is important for examining the effect of R&D activities on firm performance. Related to this, one line of the literature argues that firms should be stable in the process of accumulating knowledge. Knowledge accumulation is a long-term result of R&D efforts and must be continued with commitment whereby its nature, is different from capital accumulation (Dierckx and Cool, 1989; Sears and Hoetker, 2014). Accordingly, the persistence of R&D activities is essential. On the other hand, firms need to have strong monitoring mechanisms to ensure the quick and correct elimination of failing R&D

[1]OECD (2015), Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development.

initiatives (Swift, 2008). R&D volatility can achieve this elimination, and this is a factor that positively affects firm performance. That is, proactive management of R&D with the ability to identify and terminate underperforming R&D projects and to translate between exploration and exploitation is crucial for healthy R&D activity. This will result in observed fluctuations in R&D investments, i.e., R&D expenditure volatility, which leads to better rates in the creation of knowledge and firm performance (Mudambi and Swift, 2014). The literature on the impact of R&D level/intensity on the growth performance of firms is clearer whereas there exists limited and contradictory evidence on the R&D volatility-firm growth nexus. Motivated by this scarce literature and the abovementioned facts, this thesis investigates the impact of R&D volatility on firm growth for the Turkish manufacturing industry. Our empirical analysis covers the period 2006-2015 and mainly relies on "The R&D Activities Survey in Business Enterprises Sector Micro Dataset" collected from TURKSTAT. As R&D and non-R&D firms are not randomly selected in our dataset, to overcome the possible selection problem we use Heckman's two-stage procedure for sample selection.

We contribute to the related literature of R&D and firm growth by providing empirical evidence with a developing country case. In particular, to our knowledge, this study is the first attempt to examine the impact of R&D volatility on the growth performance of Turkish firms. Heretofore, the heterogeneous structure among firms in terms of R&D expenditure volatility which emerges as a new measure of firm heterogeneity affecting their growth performance has not been explored for Turkey either at a firm or even at the industry level. Thus, understanding the impact of the structure of R&D operations in terms of volatility on firm growth will have important implications both for researchers and policymakers. Furthermore, we move one step ahead and investigate whether tangible and intangible asset volatility has any complementary effect on the relationship between R&D volatility and firm growth. This is motivated by the fact that increasing tangible and intangible asset volatility might trigger the effect of proactive R&D investments on firm performance via helping to fulfill the strategic gaps in the renewal of knowledge and enhancing the operational structure of the firm with higher flexibility in production.

The results of the study show that R&D volatility has a positive and statistically significant effect on firm growth suggesting that R&D expenditure volatility is an indicator of the aggressive and proactive management of R&D for Turkish manufacturing firms. With the aim to reveal a more elaborated relationship between firm growth and R&D volatility, we run regressions at various percentiles of the size distribution. Indeed, we provide evidence that R&D volatility increases the growth rate of firms only after a certain threshold of size is reached. This finding implies that larger firms with proactive R&D management can develop better R&D strategies, and thus are better at successful innovations promoting firm growth via investing more effectively in R&D. Moreover, in terms of tangible and intangible assets volatility, we reveal that volatility in regarding investments amplifies the positive effect of R&D volatility on growth performance of those larger firms at the highest quantiles.

The organization of the study is as follows. Chapter 1 provides a broad literature review which contains two main parts as the theoretical background and empirical studies on R&D and firm growth. Chapter 2 demonstrates the data and the methodology of the study. Chapter 3 provides the results of our empirical investigation. Finally concluding remarks are presented.

CHAPTER 1

LITERATURE REVIEW

1.1 THEORETICAL BACKGROUND

1.1.1 Thoughts on Technology, R&D, and Innovation

Recently, the literature on research and development (R&D) and firm growth nexus has enhanced along with technological improvements around the world where the fundamental factor that paves away the developments in technology is the R&D activities of firms. The theoretical background of the relationship between R&D and firm growth dates back to Adam Smith. Smith (1776) describes innovations and inventions as an extraordinary event where he generally put the division of labor and specialization in front of R&D and innovation. Ricardo (1817) used the term 'development in machines' to refer to technological development. Ricardo emphasizes that technological development and international trade would increase economic growth, while technological development could adversely affect growth because by increasing unemployment as well.

Contrary to Ricardo, Wicksell (1923) claims technological improvements cannot displace the employees. Wicksell's optimistic model argues that with the Industrial Revolution, although technology grows at an increasing momentum, it would bring about an increase in the number of jobs. Marx (1867) states that technology increases the productivity of production units. He mainly argues that technological change enables countries and companies to grow by reducing their costs.

Schumpeter, the first user of the term “innovation” in 1912, claims that the capitalist economic system does not have a static structure. Because it is automatically self-renewed with new products and production techniques. Technological development, innovation and inventions improve the quality of the products and production techniques in general.

Schumpeter (1942) uses the term “creative destruction” describing it as the "process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one." Schumpeter emphasizes that capitalism is based on innovations and profit which is the return of these innovations (Schumpeter, 1947: 152-153). In order to achieve monopolistic high profits, firms are constantly in competition among themselves. As long as this process continues, technological development and economic growth will sustain. Schumpeter's innovative understanding reveals that innovation activities of firms generate a temporary market power as well as triggering the innovative and imitative side of their competitors. This requires accepting both R&D activities and market structure as endogenous variables from a Schumpeterian approach (Levin and Reiss, 1984).

Arrow (1962) mentions the term “learning by doing”. During the activities of R&D, firms continuously accumulate knowledge. This knowledge can spread out between the firms which are called the spillover effect (Arrow, 1962). Whilst traditional-growth theories explain that countries converge to each other over time, endogenous growth theories claim there will be no convergence, and there may arise deep gaps between countries over time because of the differences in their knowledge accumulation processes.

Solow (1957) explicitly shows that economic growth comes from technological progress. Solow expresses technology as ‘a fruit come down from heaven’ defining the technology as an exogenous factor and he does not provide any explanation for how technological development is achieved. He explains a portion of an economy’s output growth that cannot be attributed to the accumulation of capital and labor as ‘Solow Residual’ which is a measure of productivity growth.

According to Romer (1990) who is considered as the founder of the R&D-based endogenous growth models, firms move from full competition to monopolistic positions via technological developments. Romer distinguishes new production techniques gained through R&D and innovations from normal production process which can be used many

times without requiring a fixed cost. According to Romer, sustainable growth can be achieved through human capital accumulation for R&D (Romer 1990: 71-79).
In Helpman's (1997) seminal work, education and capital accumulation are outstanding issues, nonetheless their contribution to technological development is not as much as innovative actions. Helpman categorizes these actions as R&D investments, R&D’s contributions to total factor productivity and innovations in the long run. Grossman and Helpman (1990) argues that foreign trade and the R&D efforts trigger economic growth by increasing the competitiveness of an economy. Trade liberalization provides information flow across countries and thus contributes to the growth of countries in the long run. They analyse the interaction through trade and the dissemination of research and development knowledge. Accordingly, knowledge spillovers occur between firms as a result of the R&D efforts of northern entrepreneurs which devote their resources to R&D for improving product quality, while southern less-developed entrepreneurs try to learn about the manufacturing technologies of entrepreneurs in the north.

Aghion and Howitt (1992) who are inspired by Schumpeter's view of creative destruction examine the contribution of technological innovations to R&D through economic growth. According to Aghion and Howitt, there are two sectors as ‘research’ and ‘production’ in the market. As a result of the activities of the research sector, inventions and innovations arise. Thus R&D activities feed the ground for the old products and production technologies to be replaced by the new ones and pave the way for creative destruction. The different aspect of the Aghion-Howitt model is that vertical technological innovations have a quality-enhancing effect on the products, where innovations as the result of technological developments in a competitive R&D environment wear out the existing technology or products (Aghion and Howitt, 1998: 53).

1.1.2. Knowledge Accumulation, Persistence and Volatility of R&D Activities

According to Schumpeter (1942), firms develop and transform as long as they create and accumulate knowledge. There are many studies on the knowledge accumulation process of firms in the literature. Some of them claim this process as random where it is by chance that a firm that creates its competitive advantage and not its initial resources (Cantwell and Fai, 1999; Denrell, 2004). Another line of research introduces a solid background for knowledge accumulation and argues that strategic resources accumulate according to firms' intentions (Knott et al., 2003). Firms differ in knowledge because of the fact that the strategies and routines they use to accumulate knowledge are fundamentally different from each other.

According to the first view of random knowledge accumulation, the process should not be monotonous, where firms should try different methods (Kang et al., 2017; Mudambi and Swift, 2011). In addition, firms must strive for change because innovation activities lead to the rigidity trap of learning. This view also highlights the value of knowledge inside the firm and emphasizes not just knowledge but also management and integration of it. There must critical foundations for knowledge accumulation through efficient innovation and R&D operations. (Dierickx and Cool, 1989; Martin-de Castro et al., 2011). According to the opposite view, firms should be stable in the process of accumulating knowledge. Knowledge is a long-term result of accumulation efforts that is consistently maintained and must be continued with commitment whereby its nature, it is different from capital accumulation (Dierckx and Cool, 1989; Sears and Hoetker, 2014). Accordingly, knowledge accumulation has to be persistent since it is not a material accumulation. In other words, the persistence of R&D activities is essential for firms to accumulate technological knowledge.

Although the persistence of R&D is important in technological knowledge accumulation, studies in the view of persistence in R&D and innovation activities are limited. According to one line of research, intangible assets of knowledge cannot be accumulated immediately with investments in the short term. Knowledge accumulation is made by adding new knowledge on top of old knowledge, that is, it is a phenomenon that occurs in an intertemporal trajectory based on following a certain process (Dierick and Cool, 1989; Malerba and Orsenigo, 2000; Cool et al., 2016). As the knowledge accumulates, the learning by doing effect emerges and this is a sign of increasing returns to R&D efforts (Dierick and Cool, 1989; Knott et al., 2003; Le Bas and Scellato, 2014). For this reason, the accumulation of knowledge helps firms gain a competitive advantage at an increasing rate over time. Therefore, it is indispensable to ensure persistence and continuity of R&D activities in the long term where accumulated knowledge brings about the efficient creation of new knowledge with higher returns. In addition, firms with a high level of knowledge and experience have some abilities such as perception, transformation, absorption, and using technological opportunities better. Consequently, firms that continuously accumulate knowledge earn higher profits which further leads to the creation of new knowledge.

The learning process is the foundation of knowledge, thus studying the characteristics of the learning process is also important to understand knowledge accumulation. Because what has been learned in the past determines current and future learning behaviours for firms. Taking into account such path-dependency leads to more efficiency in adjusting learning strategies over time (Cohen and Levinthal, 1994; Cantwell and Fai, 1999). Additionally, even if knowledge is desired to be learned quickly in a short period of time, knowledge accumulation has some limitations since learning is a continuous process requiring stages (Cool et al., 2016).

Another line of literature points out that the sunk costs of the firms are increasing with the R&D activities (Máñez et al., 2009; Máñez et al., 2015). The learning process continues and if the R&D process stops before a result is achieved, firms cannot cover their sunk costs since the prospective profits are not achieved yet. In order for the firms to be superior to their competitors, that is, to gain a competitive advantage against them, it is necessary to continue their R&D activities and create a new product, namely an innovation product. As firms do R&D by trial and error, they acquire special talents and direct the market, which is a product of the continuous and gradual development of these talents (Cantwell and Fai, 1999; Callander, 2011).

According to the evolutionary theory, firms' behaviour and strategies are based on repetitive routines. The R&D routine determines the firm's capabilities and competitiveness in the future (Nelson and Winter, 1982). The R&D routine causes uncertainties where R&D investment causes higher adjustment costs than capital investment (Bernstein and Nadiri, 1989; Himmelberg and Petersen, 1994; Hall, 2002). Some changes, such as changes in R&D staff, and the outflow and spread of firm-specific information (whether confidential or not), can cause routines to break. Immediate changes may even cause the death of the firm (Swift, 2016). As a result, firms should continue their R&D investments persistently in order to prevent these fluctuating situations that threaten their lives (Himmelberg and Peterson, 1994; Brown and Petersen, 2011).

The persistence of R&D operations is mostly due to the Schumpeterian understanding of the dynamics in the market. A progressive mechanism of technological accumulation results from technological transformation (Long, 2021). Knowledge accumulates over time, and past R&D and innovation activities enable firms to expand their knowledge and thus their technological capacities, allowing firms to acquire knowledge effectively in future times (Nelson and Winter, 1982; Cohen and Levinthal, 1990).

In the sense of persistency and volatility, there is a distinction between the dynamics of R&D investment from regular capital investments. Because of high adjustment costs, firms have to spend a certain amount in R&D over time, which is known as the persistency of R&D (Himmelberg and Petersen, 1994). With regards to accumulating knowledge, it is critical to reducing R&D investment fluctuations by long-term dedication (Coad and Rao, 2010; Dierickx and Cool, 1989; Himmelberg and Petersen, 1994). By contrast, Mudambi and Swift (2011) claim that proactive R&D management contributes to very volatile research and development spending over time, as firms both embark on both internal and external exploitation and exploration strategies.

Investments in knowledge capital include investments which, in addition to the use of physical capital and labor, increase the productivity of firms (Marrocu et al., 2011). While R&D is a more accurate predictor of knowledge capital, future productivity growth is considerably greater for firms that spend heavily on R&D. An increase in R&D level not only improves productivity but can further boost firm growth rates.

1.1.3. The Approaches of Firm Growth

Recently, firm growth has become a popular research topic, which has been studied extensively in the literature. Practically, firm growth brings along some benefits and enable firms survive by providing them with competitive advantages in the market. On the ground that the literature has some disagreements, different assumptions and approaches to firm growth, a reasonable distinction must be made between them. Accordingly, the related literature presents six main approaches to firm growth. It has been studied by many mainstream approaches that limits firm growth with some assumptions to some other approaches that also involve the concepts of firm size, age, resources, and R&D and innovative behaviour. These approaches are as follows; neo-classical approach, stochastic approach, life-cycle approach, resource-based approach, evolutionary economics approach and learning approach.

1.1.3.1. Neo-Classical Approach

According to the neo-classical approach, firms strive to reach the optimum facility size. For that purpose, firms try to benefit from economies of scale and minimize their costs in the long run. The neo-classical approach assumes that a firm cannot grow once it reaches optimum scale. Thus, it deals with the growth of an industry rather than the growth of a firm. In this approach, the nature of the firm, why the firm emerges, and what role it plays in business cycles are investigated and the determinants of firm growth are based on market demand (Coad, 2009: 100).

In the sense of neoclassical view, the theory of transaction cost (Coase, 1937) and its relations to firm growth have been also addressed, with particular regard to acquisition and cross-country diversities (You, 1995; Kay, 2000). Using static and dynamic methods, neoclassical economics examine the relationship between firm size and post-entry performance of firms (Mazzucato, 2000). The static approach considers behaviour performance in microeconomic theory with a one-way linear path from structure to implementation, while the dynamic approach considers feedback from performance to structure.

The most important and well-known assumption of neoclassical approach is that all firms are distinguishably efficient which means that in the market whole firms are perfectly rational (Coad, 2010). The biggest weakness in the neoclassical approach is that the optimum size of the industry often limits firm growth. Therefore, the relationship between firm growth and the market structure is less realistic and lacks real facts (Storey and Greene, 2010: 236).

1.1.3.2. Stochastic Approach

The stochastic approach examines the relationship between the size distribution and the growth of firms. Gibrat's (1931) theory which investigates whether the distribution in the industry is normal or not, is one of the groundworks for the stochastic approach. Gibrat puts forward that firm growth is independent of the initial size of the firms which is referred as “Gibrat's law”. It is an assumption about the firm growth process. Accordingly, the relative changes in scale occurring in a given period are the same for all firms in a given industry regardless of the scale of firms at the beginning of the period under consideration. However, results from some empirical studies show that firm growth decreases with scale (Mansfield, 1962). Small-sized firms can capture success in the growth just like big firms. Thus, the variability of growth rates is the same for all sizes. Gibrat’s law of the proportionate effect has been studied many times where the opposite is proven, yet there exist studies that prove it (see among others Kumar 1985; Hall 1987; Wagner 1992). Mansfield (1962) who examined the birth, growth and death of firms show both parallel and opposite results to Gibrat's law. In parallel with the law of proportion, small-sized firms are observed to grow faster in the short run, but contrary to the law, small-sized firms die more easily than other large firms. In other words, firms that survive and grow in the long term are large size firms.

1.1.3.3. Life-Cycle Approach

Within the framework of the life-cycle approach, firms are born, live, and die by nature. For instance, Grenier's (1972) life cycle model purposes to describe that firm growth has two separated parts as evolution and revolution. In the evolutionary part, a firm grows with factors such as creativity and coordination. A small and newer firm is creative and innovative; on the other hand, as the firm grows it must deal with some situations. According to Grenier's model, when a firm gains competence in management, it enters an unmitigated growth phase. Right along with Grenier's life cycle model, there are several more life cycle models (see Thompson, 1976; Churchill and Lewis,1983), but all add up to the same conclusion that firms go through certain stages while growing.

1.1.3.4. Resource-Based Approach

The resource-based approach structures the firms in terms of their resources, capabilities, and competitive advantage, since firms grow and develop to the extent that they can use them. Penrose (1959) studied the combination of multifaceted resources claiming that firms within an industry are heterogeneous. Each firm that has a different amount of resource is different and their ability to use these resources is also different from each other where, for growth, these resources are more important than the demand faced by the firms. Penrose emphasizes that knowledge can be accumulated by generating resources and thus a growth process could occur by gaining competitive advantage.

1.1.3.5. Evolutionary Approach

The evolutionary approach indicates that firms are not only heterogeneous but also cannot show a consistent growth performance (Coad, 2010). This approach is often compared to the neoclassical approach explaining that not all firms should grow because there are efficient and inefficient firms within the industry. According to Coad (2010), while the growth of inefficient firms should be prevented, more resources should be allocated to productive firms. Contrary to the neoclassical approach, the pioneers of the evolutionary approach express that there are no perfectly efficient firms.

The evolutionary approach tries to concentrate on the problem of technological openness between firms which neo-classical theory cannot explain. Nelson and Winter (1982), who examined Schumpeter's creative destruction approach in their studies, focus on the learning abilities of firms, revealing technological knowledge and using effective technology. From their point of view, by developing new routines at every stage of knowledge accumulation, firms play a role in encouraging competitors to develop new routines in a competitive environment. According to Nelson and Winter (1982), as firms develop routines of acquiring knowledge, they increase their share in the market i.e., grow where other competitors are pushed out of the market. Some of the firms in the market maintain their current status, while others turn to research and development activities. As long as firms are innovative, they can pass the creative destruction stage and become a part of creative accumulation, and so they stay alive (Alchian, 1950; Coad et al. 2014). In other words, the appropriate firm stays alive and grows, while others die out from the market.

1.1.3.6. Learning Approach

It can be said that the learning approach is a part of the stochastic approach. The learning approach takes firm efficiency and firm size into consideration indicating that the survival and growth of firms depend on their efficiency levels. The productivity and growth performance of firms is positively related. In other words, the learning model implies that efficient firms grow and survive, while inefficient firms leave the market. The basis of this approach is that it takes the dynamics of firms and the productivity levels into account that enable firms to survive.

Learning models of Jovanovic (1982), Ericson and Pakes (1995) and Pakes and Ericson (1998) are closely related to Gibrat's Law. According to Jovanovic (1982), firms do not have any knowledge about the level of their efficiency until they enter the market.

Jovanovic’s noisy selection theory claims that after firms enter the market, the most efficient firms grow until they reach their minimum efficient size (MES), while inefficient firms are deleted from the market. This reveals variables such as age and size to measure the firm's ability to learn about its efficiency.

Pakes and Ericsson (1998) underline the critical role of an active learning process. As a result of the combination of an active learning process and innovation ability, it is an inevitable fact that the firms can grow successfully. According to Ericson and Pakes (1995), although firms are aware of their efficiency when they enter the market, an active learning process is a phenomenon that firms can change through investment. Firms decide to continue or leave as they are influenced by both their own investments and the investments of their competitors. That is, firm growth is a dynamic process and is driven by optimum investment strategies.

1.2. EMPIRICAL STUDIES

1.2.1. Empirical Studies Linking R&D, Innovation and Firm Growth

Schumpeter's (1942) perception of innovation has attracted attention because economic growth is considered an endogenous process. In this approach, R&D's and resulting innovations’ impact on growth is mediated by firms' entry-exit dynamics and productivity. The heterogeneous impacts of R&D activities on firms are emphasized due to the different technological structures of firms (Dosi and Nelson, 2013). For example, while some firms expand their market share by doing R&D, some firms increase their marginal profits. A range of literature has evolved by measuring the impact of R&D helping firm growth. R&D activity is related to the factors such as the size and age of firms, and the sector firms operate in. R&D’s effects on firm growth also differentiate with respect to these factors.

Empirical linkages between research and development and firm growth are advocated, with a particular focus on sales and employment growth (Aghion and Howitt, 1992; Aghion et al., 2005). The empirical literature also commits a positive link between R&D and productivity growth. Regarding the relation between R&D and firm growth in terms of employment, the literature emphasizes the labor-saving or labor-increasing effects of technological improvements. Related to this literature, product and process of innovations are differentiated where new products cause the demand expansion with an increase in labor demand. In this way, innovation achieved through R&D activity improves employment growth with such a direct demand effect. Moreover, indirect demand effects are also mentioned in the literature such as cannibalization and complementarity effects of product innovations. The cannibalization effect means that a new product replaces the old product, and it creates a decreasing effect on the labor demand. Ultimately, overall labor demand in the market is ambiguous. On the other hand, if there is a complementarity between the new and old products, labor demand will increase (Aghion and Howitt, 1992; Peters et al., 2014; Dalgıç and Fazlıoğlu, 2021).

Mansfield's (1962) intriguing work follows a comprehensive examination of the petroleum and steel industries in the USA and finds that successful innovations accelerate growth. Meanwhile, Scherer (1965) and Mowery (1983) produce similar results for the USA, where the impact of R&D as an innovation input on the growth rates of firms is explored. In addition, Geroski and Machin (1992) find that innovative firms experience higher profits and growth rates, but that growth is temporary because it is valid until new knowledge spreads to other firms. In their work, it is mentioned that innovation has two ways of affecting the performance of companies that make R&D. First, products produced as a result of the R&D activity naturally make new sales, and this innovative firm earns greater profits than non-innovative firms in the market. Secondly, affecting firm performance the only important thing is that the firm develops its internal dynamics, develops, and transforms its capabilities during doing R&D. As a result of this change and transformation, it is inevitable that the innovative firm will gain higher profits and show faster growth performance. Although cost-benefit analysis is necessary, "more perceptible, more flexible and more adaptable" innovative companies that try to make R&D investments are advantageous.

Manjon and Merino (2012) present that R&D investment is a key factor for endogenous growth of firms since it opens the door to obtaining economies of scale. Using a cross-country dataset of 754 European firms, growth is emphasized as a necessitate for business survival, and firms that want to gain market power should have a competitive advantage via R&D activities. However, low-technology firms do not obtain noteworthy profit from R&D investments, while high-technology firms obtain more profit.

The effects of R&D give different results on firm growth due to the different types of firms such as low-growth firms and high-growth firms (Coad and Rao, 2008). Segarra and Teruel's (2014) study analyses the relationship between R&D investment and firm growth from this perspective. In this study, Spanish Community Surveys are used for 3.807 Spanish manufacturing and services firms between 2004 and 2008. The results of the study show that internal R&D investments have a higher impact on the upper quantiles of growth distribution, while external R&D investments have a significant positive effect on the median. Their search also presents sectoral differences between manufacturing and services firms. The impact of R&D is higher for manufacturing industries.

The literature linking R&D performance and firm growth in terms of the distinction between high growth firms (HGF) and non-high growth firms (non-HGF) arises from Birch's (1981) report stating that small firms create job generation in the U.S. When the report is reviewed, it appears small-sized firms have a disproportionably bigger effect on the new job creation. Some studies are inspired by Gibrat's Law (1932) as firm growth rate does not depend on own firm size, and they defend that the job creation effect is just random. For example, Moreno and Coad (2015) find out that small-sized enterprises grow faster than large-sized firms. Daunfeldt (2010) rejects Gibrat's law and presents that small firms show greater growth rates rather than large-sized firms.

Firm age is also considered an important factor in measuring the impact of R&D and innovation on firm growth as well as the firm size. Fort et al. (2013) who adhere to this argument, claim that firm age is linked to firm growth more than firm size. In spite of the fact that empirical literature is uncertain about the decisive role of size or age on firm growth, there are some stylized facts about size and age. According to systematic analyses of twenty research papers about HGFs, Henrekson and Johanson (2010) state that, HGFs are found to be smaller and younger than non-HGFs.

Coad and Rao (2008) display that patents and R&D expenditures are causal only for HGFs. Stam and Wennberg (2009) demonstrate that firm R&D is positively related to the growth performance of HGFs. They emphasize that these effects generally appear in start-ups. Although the evidence is uncertain, Goedhuys and Sleuwaegen (2010) reveal that being an HGF is positively related to product innovations, but negatively related to process innovations. Smallbone et al. (1995) assert that product innovation is done by small and medium-sized HGFs in the UK. Navaretti et al. (2014) claim that firms' growth performance at the higher percentiles of the growth distribution is enhanced by the firm's R&D inputs however, R&D outputs improve firms at the lowest percentiles of growth distribution. Colombelli et al. (2013) expose that the activity of R&D and innovative efforts influence the sales growth of firms at the high-end percentiles of the growth distribution. Bianchini et al. (2016) analogically expose that R&D activities and innovation products impact sales growth of firms only at the level of upper quantiles. Segarra and Teruel (2014) mention the distinction between internal and external R&D efforts, and they expose that whereas internal R&D efforts impact the firm growth positively positioning at the upper quantiles, external R&D efforts is actualized for the firms positioning at the median quantiles.

Innovation which is an output of R&D is investigated by Mansury and Love (2008) in terms of the performance of US services firms. The study emphasizes that there are some differences in the methods of innovations made by service and manufacturing firms. For instance, organizational change is a substantial factor of an innovation output for service firms, while manufacturer firms give importance to in house R&D. In addition to that, ‘soft’ skills like collaborative and workforce abilities are an important factor for services firms, while ‘hard’ skills like that flexibility of production methods and R&D competence are crucial for manufacturing firms. Mansury and Love (2008) examine 206 US service firms where their results show service innovations and their scope has a constant positive impact on firm growth, though no impact on firm productivity.

Lee (2010) focuses on the dual role of R&D, as the effect of knowledge generation and the technological competence enhancing and its implications on firm growth. The study handles with several countries such as Canada, Japan, Korea, Taiwan, India, and China. Lee shows that firms differentiate depending on the size of their technological knowledge stock and their ability of technological competence enhancing capability. Thus, firms which have the ability of low technological competence enhancing are inclined to gradually declining growth pattern (convergent growth pattern), while firms which have high technological competence enhancing are inclined to sustain a vicious growth pattern.

As previously mentioned in this section, the source of the stochastic approach which is Gibrat’s Law is defined as the rule of stating that the proportional rate of growth of a firm is independent of its absolute size. According to the Schumpeterian view, it was investigated whether firm size could be an advantage in R&D effort thanks to role of economies of scale (Kamien and Schwartz, 1982). The related literature demonstrates two kinds of effects on the relationship between firm size and growth with an advantageous effect of the firm size emerged in technological progressive industries with research and development activities while there is no linkage between size and growth in non-R&D performing industries (Amirkhalkhali and Mukhopadhyay, 1993). Demirel and Mazzucoto's (2012) seminal work on the relationship between firm size and firm growth provides evidence that the impact of R&D conducted by small and large pharmaceutical firms on growth can be different. Examining firm growth in the US pharmaceutical industry between 1950 and 2008, they show that while R&D investments are positively significant for the growth of small-sized pharmaceutical firms, they are not effective for the growth of large firms. In fact, R&D investments slow down large firms’ growth instead of contributing to high growth. Demirel and Mazzucoto's (2012) study thus, demonstrates the ineffectiveness of large pharmaceutical firms in terms of R&D, where large pharmaceutical firms (such as Pfizer and AstraZeneca) closed some R&D branch offices in different countries.

Coad et al. (2016) show that the effect of R&D on sales is larger than that on labor productivity and employment. Notwithstanding, the impact on sales and employment is bigger for young firms, whereas the impact on labor productivity is larger for old firms. This impact may be since old firms fund R&D operations in order to pile up their efficiency and make capital out of their economies of scale, whereas young firms attempt to grow to arrive at a minimum efficient scale. Besides, R&D is less risky for older firms (Coad and et al. 2016). Huergo et al. (2004) also investigate the role of firm age and demonstrate that concerning the productivity growth impact of process innovations introduced by firms along their different ages, new born firms tend to exhibit higher productivity and growth rates. Spescha (2019) discovers that smaller and more mature firms exhibit a larger effect of R&D expenditures on sales growth for Switzerland.

Hall (1987) reveals that for US manufacturing firms in the period of 1976-1983, the R&D investments per employee has a positive effect on the firm growth irrespective of firm size. Coad and Grassano (2019) examine the EU's industrial R&D investment and they find weak evidence on the effect of R&D expenditures on the growth process of firms. In addition, their study reveals that R&D investments do not have an immediate impact on sales and profit growth while it is an element of uncertainty and can bring both failure and success. Moreover, Castellacci (2011) analyses Norway firms in the period of 1998-2006, and he discovered sales and labor productivity rise as a result of R&D investments. Bogliacino et al. (2012) find that R&D investment has a positive impact on employment growth in their study investigating European firms over the period 1990-2008.

Monte and Papagni (2003) investigate the relationship between R&D and the growth of firms using a panel of Italian firms. They indicate that the sales growth rate of firms increases with R&D intensity. Italian firms gain a comparative advantage across not only domestic firms but also foreign firms with patent rights obtained as a result of research and development. Falk (2012) investigates the relationship between R&D intensity and firm growth using a firm-level data set for Austria over the period 1995–2006. They take two R&D intensity measures as the ratio of R&D employment to total employment and the ratio of R&D expenditures to sales. Their results show that R&D intensity has a substantial effect on both sales and employment growth within two years where the effect of R&D goes down significantly as time progresses. Another important aspect of Falk's paper is that the R&D intensity has a different impact on firm performance with high and low growth. It is shown that R&D intensity positively affects firm growth at the middle and upper quantiles of growth distribution. By contrast, firms at lower quantiles cannot take the advantage of R&D investment. Similarly, examining US firms, Morbey and Reithner (1990) find that sales and productivity growth are positively affected by R&D intensity. Yasuda (2005) finds similar results in his study investigating Japanese manufacturing firms covering the period 1992-1998 and presents that R&D investment per employee boosts employment growth. In the seminal study, the relationship between R&D investment and firm growth was measured. In their research on Portugal SMEs, Nunes et al. (2012) observe a negative relationship between R&D intensity and sales growth for non-high-tech firms, while a U-shape relationship is observed for high-tech firms. Oliveira and Fortunato (2016) who examine the relationship between R&D and firm growth in Portuguese manufacturing firms find that R&D investment does not affect the firm growth rate, namely discovered that R&D investment is negligible to affect employment growth. They claim there is no certainty that R&D activities will positively affect the growth of firms because R&D contains risks by its nature.

1.2.2. Empirical Evidence on The Persistence and Volatility of Knowledge Accumulation

1.2.2.1. Persistence of Innovative Activities

In this part of the thesis, current studies in the literature examining the determinants of the persistence of R&D and innovation activities, and the relationship between the persistence of R&D efforts and firm performance are investigated.

Past R&D activities have an impact on current or future R&D activities highlighting the persistence of R&D activities. In his study on German firms, Peters (2009) examines how firms that have R&D activities in period t-1, continue their activities in the following periods. Firms that did R&D in period t-1 continued to make R&D more persistently with respect to other firms. Other studies for Spanish manufacturing firms find similar evidence on the persistence of R&D (Castillejo et al., 2004; Mañez et al. 2009). Woerter (2014) who investigates the impact of market competition on the persistence of R&D investment find the degree of persistence taking an inverted U-shape. When there are 6-10 primary competitors, the desire to retain R&D investment is strong, while when there are 50 or more competitors, it is weak. Bloom (2007) looks at the relationship between persistence and ambiguity. Increased volatility in the firm's internal and external markets provides a greater opportunity to continue R&D activity.

Geroski et al. (1997) study patent applications for UK and US firms and shows that many firms have poor patent durability, while only a few firms have high persistence. Cefis and Orsenigo (2001) uses the transfer likelihood matrix to calculate the persistence of patents in five countries and finds that firms with more patents have a higher persistence rate. This is also proven by a study examining 577 British firms (Cefis, 2003). According to the results of the Cefis (2003) study, most firms are found to occasionally create knowledge. Swedish firms are examined by Tavassoli and Karlsson (2015) and it is found that persistence is valid not only for product innovation but also for process innovation. Ganter and Hecker (2013), who classifies product innovation into two as the product new to the market and new to the company, discovers that the product innovation which first enters the market shows persistence, but the first product innovation of the firm does not.

It is important to understand and examine the characteristics of the firms in terms of their persistence to carry out R&D activities. Starting from here, according to many studies that examine the duration and determinants of R&D and innovation activities, the average time for firms to continue their innovation activities is approximately 5 years. A study for Spanish manufacturers reveals that firms with more knowledge who actively engage in basic research are closer to sustain their innovation activities (Triguero et al., 2014). The determinants of the persistence of R&D activities in Spanish SMEs are examined by Manez et al. (2015). They find that firms with a greater R&D stock, more product innovation, and with higher sunk costs continue to have a strong desire to continue R&D. Jang and Chen (2011) examine the factors affecting patent duration in Taiwanese IT manufacturers, reveal that firms' average patent term was 2.18 years. In addition to this, firms that have more patent stock at an early stage incline to continue their innovation activities. As the knowledge accumulation is high, the learning effect kicks in, and it becomes easy to create new knowledge. Apart from this, industrial growth rates, firm size, and profitability have a remarkable effect on the execution of patent activities.

1.2.2.2. R&D Volatility and Firm Performance

Several studies explore the effect of R&D persistence on firm performance, where empirical findings are still uncertain. According to Cefis and Ciccarelli's (2005) pioneering study who investigate the effects of persistence of innovation activities on firm performance, the patented firms have superior profits. Johansson and Lööf (2010) discover that permanently R&D-making firms have higher growth rates in sales, productivity, and exports than others. Demirel and Mazzucato (2012) classify 2.895 Swedish firms into three categories as persistent R&D firms that carry out R&D activities each year, temporary R&D firms that do not conduct R&D activities at least once, and non-R&D firms that do not conduct R&D activities at all. They find that only the firms that continue to engage in patent activities have a positive effect on firm growth. For instance, Deschryvere (2014) who conducted research on Finnish SMEs using CIS over the period 1998-2008, reveals that the positive relationship between R&D and sales growth continues as long as innovation efforts sustain.

Triguero et al. (2014) investigate the persistence of innovation on employment for Spanish manufacturing firms. They find that innovation activities at the firm level have a positive impact on employment emphasizing the difference between process and product innovations on the employment factor. Accordingly, R&D growth and sales growth are positively connected, but this is only for product innovators. In addition, differences emerge between small-medium sized and large-sized firms.

The effect of R&D on firm growth can be better understood systematically in regards of the persistence of R&D operations. When the level of R&D activity and the persistence of R&D activities are combined, knowledge accumulation is better captured. Higher firm performance including firm growth arises with the launch of R&D activities, innovative products, and processes. Falk (2012) analyses Austrian companies and indicates that as firm age grows, the favourable effect of R&D investments on its growth diminishes. Wöhrl et al. (2009) show that R&D investment plays an important role in firm growth throughout the life of the firm as innovation is a continuous learning process characterized by internal trial and error. Segarra and Teruel (2014) argue that the more a firm invests in R&D, the more likely it is to become a high-growth firm. The Crépon-Duguet-Mairessec (CDM) model defines the relationship between R&D, innovation and firm performance underlining the importance of the R&D level. From the perspective of this model, the higher the R&D level, the more benefits arise for firms (Crépon et al., 1998; Castellacci, 2011).

In the related literature, the processes of seeking and accumulating knowledge require long-term and persistent efforts. This is because R&D activities are a phenomenon with uncertainties where trying to reduce this uncertainty through long-term channels of trial and error and learning by doing is crucial for success (Coad and Rao, 2010). For example, Cefis (1999) who analyses UK firms find that improvements in long-term, rather than short-term innovation practices impact firms' stable profitability. As a good example of this, the Sony company is presented as evidence. With its deteriorating performance, Sony invested a certain amount annually in R&D despite the rapid change in its industry. The result is that by developing an image sensor technology, it took the role of the leader company with the highest operating profit in the last 20 years. Accordingly, the minimization of resource flow fluctuations and persistent R&D is needed for efficient knowledge accumulation.

From another perspective, the related literature also emphasizes that while real capital can be bought or accumulated by short-term efforts, knowledge is not accumulated simply by increasing the amount of knowledge flow (Dierick and Cool, 1989; Knott et al., 2003). As firms accumulate an intangible asset, differences occur between their learning behaviour such as persistence or in-persistence (Arrighetti et al. 2015). Thus, there are significant variations in the volatility of R&D investments among firms. As for the R&D volatility on firm performance, some part of previous research indicates that R&D volatility increases the volatility of future earnings (Kothari et al. 2002). This literature argued that even if the R&D volatility increases firm level volatility, it is not a harmful factor for firms. On the contrary, it is a precursor of controlled growth. In other words, firms that take a break from R&D to see if their R&D efforts are paying off are more likely to earn a competitive advantage (Comin and Mulani, 2009). Thus, R&D expenditure volatility is a newer measure of firm performance because, according to some research, if R&D volatility is successfully controlled, considerable increases in firm performance and successful growth occur. Until reaching the right output from R&D investments, controlling R&D requires firms to have strong internal governance processes. Naturally, in this process, the firm has more fluctuating R&D investment patterns. High R&D fluctuation indicates the presence of a high level of technological domain expertise and monitoring activity that allows the firm to distinguish between good and bad R&D projects (Bernardo et al., 2001; Stein, 2003).

1.2.2.3. Proactive R&D Management and Firm Performance

The literature argues that there are some reasons for R&D volatility such as R&D manipulation hypothesis (Degeorge et al., 1999); internal and external financial factors (Myers and Majluf, 1984); asymmetric information of R&D (Hall and Lerner, 2010); the existence of transaction costs (Williamson, 1981); technological capability (Kang et al., 2017); and proactive management (Mudambi and Swift, 2011). Studies related to the R&D manipulation hypothesis show that managers routinely manipulate their R&D investments to adjust R&D expenditures and to adjust earnings (Degeorge et al., 1999). If the gain is less than predicted, the firm immediately cuts its R&D expenditure. On the other hand, firms are heavily dependent on internal finance that is a source of R&D investment because external finance is very expensive, and inherently internal finance has a changeable structure too often (Myers, 1977; Myers and Majluf, 1984).

R&D requires a certain amount of knowledge and this knowledge which is an intangible asset can be spread to other firms and create a spillover effect. However, the knowledge does not always spread correctly and, firms might have R&D volatility due to the presence of asymmetric information (Hall and Lerner, 2010). In terms of the transaction costs approach, these costs escalate even greater as information is scarce and R&D investments become unpredictable (Williamson, 1981). Investors need higher risk premiums or more assurance to offset transaction costs with respect to those for ordinary investments.

One important approach to R&D volatility is about proactive management of R&D which could further lead to better firm performance. According to Mudambi and Swift (2011) and Kang et al. (2017), firms' management of the R&D expenditure process should include two key components of 'proactive management' and 'technological capabilities. They show that more fluctuations in the R&D expenditure of the firm are linked to stronger firm growth. There exist other studies emphasizing the role of proactive R&D investments in R&D volatility as well as linking this concept to better firm performance in terms of growth. For example, Swift (2013) expresses that thanks to the proactive management of the firm's R&D function, a strong and positive linkage between R&D expenditures volatility and firm performance could be observed. Mudambi and Swift (2011) who examine 11.000 US manufacturing firms discover that more fluctuations in R&D expenditure of the firm are linked to stronger firm growth. The volatility in R&D activities is actually caused by the sudden cessation of R&D activities. According to Mudambi and Swift, the activity in the R&D lab is frequently and significantly disrupted by proactive management of R&D expenditure since such management routines do not allow R&D projects with low commercial expectations to continue. Patel et al. (2017) explore that firms with more effective corporate governance outperform in the face of rising R&D volatility for UK firms. According to their study, the volatility of tangible assets increases R&D volatility returns, but this relationship is not affected by intangible asset volatility. Thus, proactive R&D investment management serves better firm growth via R&D volatility. Kang (2018), who examines 2,456 Korean firms between 2002 and 2009, states that technological capability is a determinant between a firm's persistence and volatility, and volatility is necessary when considering changes in internal cash flow and proactive management.

The managers of firms have often myopic behaviour when investing in R&D (Degeorge et al., 1999). That is, R&D investments are continued regardless of whether an efficient outcome is obtained. Over time, firms have higher know-how and tracking standards of projects, enabling them to differentiate between good and bad R&D projects by adjusting their R&D activity expenses (Patel et al. 2017). It is a fact that continuous but unsuccessful R&D expenditures will not be beneficial for the growth of firms and may even cause a loss of firm resources. Hence, contrary to popular belief, R&D persistence may not be a situation that can benefit the firm. Mudambi and Swift (2011), strikingly find that US firms with volatile R&D investments have higher growth rates. Namely, contrary to the popular belief, volatility of R&D investments could encourage greater learning and improved efficiency of R&D efforts.

The creative–destructive viewpoint assumes that if R&D volatility is caused by effective governance of the funding allocation to R&D operations, it can be beneficial in reactivating future research activities (Schumpeter, 1942; Swift, 2008). New production units replace old products and firms that actively deal with R&D expenditures to create value and manage the product and process innovation mechanisms correctly benefit more from R&D. Namely, according to the creative–destructive approach, volatilities in R&D are caused by effective governance of R&D funds. Duppati et al. (2017) show that Spanish firms which have up and downs in their R&D expenditures perform better. He indicates the corporate management of the firm plays an important role in the relationship between R&D spending volatility and firm performance. Swift (2013) examines the relationship between R&D volatility and firm performance and US manufacturing firms and find that a positive association where increased organizational slack strengthens the positive relationship between R&D expenditure volatility and firm performance. The term "organizational slack" refers to the resources open (excess resources) to a firm that is not required to meet immediate corporate and operating needs. Thus, organizational slack is seen as a key source of R&D. It should be used to support peaks in R&D expenses and effects on firm's risk orientation. Bourgeois (1981) indicates that firms which maintain organizational slack provide a surplus of available funds to encourage innovation. Firms which have higher organizational slack can proactively manage their R&D investments and the resultant R&D volatility can positively affect firm performance (Swift, 2013).

The related literature also highlights the importance of managerial self-confidence on R&D activities. Top executives have more power and are more likely to become overconfident and, as a result, invest more aggressively in R&D operations due to poor internal governance and the absence of external monitoring systems (He et al., 2019). Wang et al. (2018) who use a sample of 1293 Chinese firms, find that managerial overconfidence is able to foster firms' R&D intensity. Furthermore, managerial overconfidence plays an important role in R&D persistence and volatility under positive and negative shocks (Wang et al., 2018). Negative and positive shocks are separated as positive and negative factors and actually create asymmetrical reactions on the firm. In terms of positive and negative shocks affecting R&D investment, the firm's persistence or volatility in R&D is not a dichotomous selection problem (Kang et al., 2017). As technological capability increases the internal cash flow and sales increase compared to the previous year's sales, this causes increase in volatility of R&D investment, which is positive shocks. In contrast, when profits fall short of the previous year's sales, it is negative shocks; and technological capability balances the internal cash flow and creates persistency in R&D spending. Thus, according to Kang et al. (2017), one reason for the R&D volatility is that technological capability differs from firm to firm. That is investment in research and development is not a dichotomic choice between persistence and volatility and depends on the technical capabilities of each firm.

1.2.2.4. Transition Between Exploration and Exploitation

The concept of transition between exploration and exploitation is a further issue in R&D and innovation management strategies of firms (Danneels, 2002; Rothaermel and Deeds, 2004). Ineffective R&D governance prohibits the firm from shifting between exploration and exploitation modes when market conditions require, and this results in stable R&D investments (Swift, 2013). However, exploratory and exploitative R&D are choices based on discovering new technologies and markets to reap future benefits, as well as improving existing technologies and preserving current profits (Gupta et al., 2006; Tushman and 'O'Reilly, 1996). As exploration and exploitation are complementary processes, it is increasingly important for firms to strike a balance between these two terms (March 1991; He and Wong, 2004). Examining the relationship between these two terms in terms of innovation, Yalcinkaya et al. (2007) reveal that exploratory innovation focuses on developing new technologies and designing new products, while exploitative innovation focuses on maintaining existing products and expanding product portfolios via lower input.

According to Mudambi and Swift (2011), who found that the volatility of R&D spending is positively associated with firm growth, firms are transitioning between cycles of low and high R&D operation. This transition occurs between exploration and exploitation. If firm exhibits transition from exploration to exploitation in a sequential manner, then there is relatively volatile R&D expenditure profile over time (Di Masi et al., 2003). While exploitation activities are defined as activities in which the firm uses its existing knowledge base, exploration refers to the search for new knowledge in areas that are relatively far from the firm's core knowledge base (Rosenkopf and Nerkar, 2001; Baum et al., 2000; Benner and Tushman, 2003; He and Wong, 2004). In other words, exploration practices help firms gain new knowledge, whilst exploitation activities help it develop useful innovations (March, 1991; Levinthal and March, 1993). According to Mudambi and Swift (2011) there is nothing more natural than a fluctuation in R&D investments of firms that implement proactive exploitation and exploration management, and they are linked to improved firm performance. If firms focus too much on exploratory innovation, they may not earn enough commercial gain and can fall into the "innovation trap" (Cockburn et al., 2000). In other words, the fact that firms spend on R&D without slowing down indicates that they are in myopic behaviour, and it should not be ignored that firms may not make long-term profits.

There are two different types of R&D expenditure volatility as positive R&D expenditure volatility and negative R&D expenditure volatility in terms of the direction in which firms shift between exploration and exploitation (Hai et al., 2020). Positive R&D volatility is the transition from exploitative innovation to explorative innovation. Positive R&D volatility, which means firms discover new technologies and processes, refers to the rapid changes in technologies, but also refers to the adoption of new distribution channels / new market opportunities to develop against any fluctuations in product demand and material supply (Abernathy and Clark, 1985; Tripsas, 2008). On the other side, negative R&D volatility is an indicator of transfer from explorative innovation to exploitative innovation. Negative R&D volatility improves the quality of the products that firms acquire through heuristic innovation, provide optimization, increase the efficiency of R&D processes, help firms increase their market shares and ensure a stable economic return in the long run (Hambrick and Mason, 1984; Saunila and Ukko, 2014). Oscillating between exploration and exploitation to achieve sustainable competitive advantage is a crucial factor for firms when investing in R&D, although the movement between these two could cause volatility in R&D investments.

1.2.2.5. The Complementary Effect of Tangible and Intangible Assets Volatility on R&D Volatility

A non-physical asset is referred as an intangible asset and it includes knowledge, goodwill, name awareness, know-how and intellectual property such as patents, trademarks, and copyrights (Hall, 1992; Villalonga, 2004). Tangible assets are property, vehicles, machinery, and inventory in contrast with the intangible assets. Adding tangible and intangible asset volatility to R&D volatility can boost firm performance much further.

Increasing tangible asset volatility might trigger the effect of proactive R&D investments on firm performance by helping to fulfill strategic gaps in the renewal of knowledge.). The reason behind tangible asset volatility is that firms aim to minimize the deterioration of tangible assets. Thus, tangible asset volatility helps to enhance the operational structure of the firm, which is a physical element to reinforce the gains from R&D volatility. As firms do not reduce their operational assets despite increased R&D volatility, higher tangible asset volatility indicates higher production flexibility (Patel, 2017).

Firms that can successfully move between exploration and operation periods are likely to have precious intangible resources. Intangible assets are used to benefit from R&D investments where these deeply embedded assets are based on expertise and knowledge inherent in the firm. Moreover, since these assets are based on organizational capabilities within the firm, they cannot be transferred to another firm and valuable for monitoring firms' R&D activity successfully. Therefore, returns on intangible assets result in superior R&D management and firm growth. Itami (1987) suggests that all concepts such as technology, brand name, firm culture are intangible assets, and these assets are the only element used by the firm to gain competitive advantage over its peers. Firms that proactively evaluate and manage their intangible asset stocks can increase their earnings from R&D investments over time. Proactive management of intangible assets requires firms to spend and revalue these assets frequently (Powell, 2003).

In the firm's knowledge-based view, increased volatility of intangible assets refers to the renewal of intangible assets, and diseconomies can be eliminated as this will increase asset stocks (Dierickx and Cool, 1989). Firms can use resource management effectively by managing intangible asset volatility and R&D volatility together. The fluctuating R&D expenditures and intangible asset values generate new opportunities for firms. Namely, intangible assets facilitate to gain competitive advantage because of their implicit, dynamic, and complementary nature (Knott et al., 2003; Kothari et al., 2002; Pike et al., 2005).

Rigidity in intangible assets can lead to lower benefits from R&D investments, which may again result in core rigidities (Leonard-Barton, 1992). Thus, we understand that R&D volatility and intangible asset volatility play a complementary role in improving a firm's performance. The adjustment of intangible assets which covers knowledge, patents, human capital, human resources, brand value and processes can increase the gains from R&D volatility.

1.2.3. Empirical Studies on Turkey

The related literature on Turkey mainly consists of macro-level studies examining the relationship between R&D and economic growth. These studies based on aggregate data usually make long-term and short-term causality analyses of the relationship between R&D and economic growth applying different econometric methodologies. Among them, Altın and Kaya (2009) and Korkmaz (2010) discover that R&D investments cause increases in GDP in the long term, whereas there is no relationship between R&D and economic growth in the short term. In a similar study, Doğan (2011) investigates the relationship between R&D investments and economic growth over the period 1992-2006. He finds a co-integration relationship in the long run where R&D is the only source of growth. Bozkurt (2015) employs a vector error correction model using Johansen co-integration tests and finds that economic growth triggers R&D investments in Turkey between 1998 and 2013.[2]

In a firm level study on R&D decision, Kalaycı and Pamukçu (2011) examine the effects of the foreign direct investments (FDI) on R&D activities for Turkey over the period 2005-2007. The results of their study show that FDI negatively impacts on R&D investments in manufacturing sector. Foreign investors' investment in R&D activities in Turkey, are less than the R&D investments made by domestic firms; and it has less impact on the manufacturing sector. Özçelik and Taymaz (2008) discover that subsidies such as government support programs positively affect R&D investments of Turkish

[2] See also Tarı and Alabaş (2017); Ülger and Uçan (2018); Tuna et al. (2015) for similar analyses in Turkey.

manufacturing firms. According to Utku and Pamukçu (2009), for Turkish manufacturing industry, the decision of a firm to engage in R&D activities varies according to the industry the firm operates in, size, age, and the growth rate of the firm.

There are a few numbers of micro-level studies examining the relationship between R&D and firm performance. For instance, Ülkü and Pamukçu (2015) investigate the relationship between knowledge diffusion and firm productivity. Particularly, using firm-level data from manufacturing industry, R&D intensity and channels of knowledge diffusion are examined. They show that R&D intensity increases firm productivity only for firms at some threshold of technological capability. Dayar and Pamukçu (2014) reveal that the endogenous attempts of R&D activities of manufacturing firms and their physical capital stock intensity positively impact firms' labour productivity.

Traş et al. (2016) try to shed light on the factors affecting the R&D decision of firms, examining the World Bank's data obtained from the Turkey-Business surveys in 2013-2014 and using Heckman's (1976) two-step selection methodology. They particularly employ data for 693 firms where only 43 firms were found to have positive R&D spending. Their results show that the scale of the firm measured by total sales positively affects the R&D decision while it negatively affects the expenditures made for R&D. The age of the firm has a statistically significant but negative impact on the decision of R&D participation. Moreover, government support is an important factor for firms to make R&D activities. In a similar study for Turkish manufacturing firms, Limanlı (2015) shows that some factors such as sales, subsidy, share of foreign ownership, competition incentive, domestic and foreign trade shares have a crucial role in terms of taking R&D decision.

Ayaydın and Karaaslan (2014) use data for 145 manufacturing firms covering the period 2008-2013 in Turkey and, show that R&D activity increases the financial performance of the firms. Günday et al. (2011) examine the effect of innovation activities on production, market and financial performance using data of 184 manufacturing firms from six sectors (textile, chemical, metal products, machinery, electrical home tools and equipment and automotive industries) within the region of Northern Marmara. The findings of their study show that innovation has a positive impact on manufacturing firm performance.

In a recent study using firms' applications to the national patent institute as a proxy for product innovation, Kılınç (2018) finds a positive and significant impact of product innovation on employment growth of firms in manufacturing and services sectors over 2006–2016. Within the manufacturing sectors, the effects are more pronounced in transport equipment, leather, computer and electronics, whereas construction, architectural, and engineering services that benefit the most from innovation in services. According to Öztürk and Zeren's (2015) study, R&D expenditures have a positive effect on sales growth in the manufacturing industry, and this effect continues during six months. In a similar study with limited number of firms, Atalay et al. (2013) conduct a survey on top managers of 113 firms in the automotive supplier industry and demonstrate that as of the year 2011, product and process innovation affect firm performance positively. Ar and Baki (2011) demonstrate that investments of R&D effect on firms' product and process innovations and also promote performance of sales and market shares of firms.

Studies conducted with community innovation surveys (CIS) data in the related literature have gradually become more popular. However, firm level research using CIS data is very limited for Turkey. Lo Turco and Maggioni (2015) investigate the causal link between firm innovation activity and export performance by using CIS data in 2008 wave covering 2822 Turkish manufacturing firms. They reveal that process and product innovation influence firm profitability by different channels. Fazlıoğlu et al. (2019) examine the productivity and innovation connection for Turkish manufacturing firms employing endogenous switching techniques and CIS data over 2003–2012. They find internal R&D is more effective for firms than outsourced R&D for productivity improvements.

In a recent study, Dalgıç and Fazlıoğlu (2021) examine the effect of innovation on firm growth for Turkish Manufacturing and Services SMEs using CIS data over the period 2003-2015. They particularly examine the innovation and growth relationship with a special focus on high growth firms. Dalgıç and Fazlıoğlu (2021) demonstrate that the positive effect of innovation on firm growth could differ for manufacturing and service firms with a more pronounced effect for manufacturing firms. In addition, the impact of innovation outputs on firm growth is markedly greater than the impact of innovation inputs.

CHAPTER 2

2. DATA AND METHODOLOGY

2.1. SOURCE OF DATASETS AND DATA CLEANING

The data utilized in this thesis are constructed on recent and comprehensive firm level datasets from various sources collected by the Turkish State Institute of Statistics (TURKSTAT). The datasets are available under a confidential agreement by which all the elaborations can only be conducted at the Microdata Research Centre of TURKSTAT under the respect of the law on the statistic secret and the personal data protection.

The main source of dataset is *The Research and Development Activities Survey in Business Enterprise Sector Micro Data Set (R&D Surveys)*. Data on R&D expenditures in the R&D Survey are compiled in accordance with the Frascati Manual, which defines R&D as ‘creative work undertaken on a systematic basis in order to increase the stock of knowledge of man and society, and the use of this stock in order to devise new applications’ (OECD, 1993). The R&D Survey, conducted at the enterprise level, covers all R&D performers subsidized by a variety of (semi-) public funding organizations, enterprises located in Technology Development Zones, and the largest 500 R&D performers in the past R&D surveys.

The microdata set of the Research and Development Activities Survey of Financial and Non-Financial Institutions in 2019, which was called the Research and Development Activities Survey of Industry and Service Enterprises before the 2016 reference year, contains main tabulated results, methodological information, and principles on microdata. The micro data provided in this micro-data set can be used to generate cross-tables, perform different statistical analyses, and run econometric models.

Since the 1960s, most OECD member countries have been compiling R&D statistics on a regular basis. The first Research and Development Activities Survey was conducted in collaboration with TURKSTAT and the Turkish Scientific and Technological Research Council. This first study contributes significantly to the evaluation and development of policies in this field and addresses a significant gap in Turkey's Science, Technology, and R&D. It was carried out between May 1991 and May 1992 in accordance with the "Frascati Manual, Guidelines for Collecting and Reporting Data on Research and Experimental Development" prepared by the OECD. From that date TURKSTAT produces annual statistics based on this research and makes them available to the public.

According to the System of National Accounts, financial and non-financial companies' statements have been used by the business enterprise sector since 2017. R&D surveys, offer information about R&D and R&D staff by the performance sector listed. R&D spending can be divided by fund source, scientific area, cost type, type of operation, R&D category, and research fields. Data on R&D personnel can be separated by occupation, qualification, gender, and scientific fields. All corporations that exist in the industry and services sectors recognized or expected to have R&D are included. As a result, the R&D surveys' coverage consists of enterprises that are considered to engage in R&D; enterprises based in Technology Development Zones; enterprises whose R&D operations are funded by public agencies; enterprises who have benefited from indirect R&D assistance under Law No. 5746; and by turnover and value added, the top 500 enterprises of industry and service sector.

In terms of methodology of the R&D survey, the data is gathered directly from the company through a web survey where TURKSTAT has assigned each user a username and password in the sense of data collection. The data entered by respondents into the web environment is first checked by TURKSTAT's Regional Directorates. Following the micro-level control and accuracy review, the relevant group conducts more comprehensive and macro-level analyses, and suspicious documents are returned to the Regional Directorates for a final decision. Moreover, the survey questionnaire is prepared on behalf of national and foreign organizations, in accordance with concepts and standards in the Frascati Manual.

The second dataset exploited in this thesis is *The Annual Industry and Service Statistics (AISS)*- it is a census for the firms with more than 19 employees whereas it is a representative survey for firms with less than 20 employees. In the dataset, firms are classified with respect to their main activity, whilst identified by NACE Rev 1.1 and Rev.2 standard codes for sectoral classification of Eurostat.[3] The database provides detailed info on a number of structural variables that are primarily seen on a firm's balance sheet such as value added, revenues, labour costs, intermediate inputs costs, tangible investment costs, intangible investment costs, information on geographical location and industry affiliation, the number of employees as well as the information on foreign ownership that classify firms between domestic, mixed ownership and purely foreign ownership status.

The third main source of data utilized in this thesis is *The Annual Trade Statistics (ATS)* which includes foreign trade flows of individual firms that are sourced from customs declarations. The trade flows of goods are collected for the whole universe of exports and imports at 12-digit GTIP (Customs Tariff Statistics Position) classification, the first 8 digits of which correspond to CN classification (Combined Nomenclature of EU based on the 6-digit Harmonized System classification) whilst the last 4 digits are national.

For the analyses, the three datasets are matched utilizing a common firm identifier. The original sample sizes in the merged datasets were slightly larger yet merging the datasets was not straightforward and we applied an extensive screening and time-consuming data cleaning process that is principally inspired by Hall and Mairesse (1995). We removed abnormal observations (i.e., missing, zero or negative) for the main variables such as intermediate inputs, output, value added, labour cost etc. We excluded observations where the main variables and ratios (i.e., employee, sales, capital per employee, value

[3] The economic activities covered are NACE sections C to K, and M to O.

added per employee) show excessive variation. Particularly, since we cannot follow mergers and acquisitions of firms from data, we drop the firms with employee growth rate above 300 percent and below -250. The limits were set different than that of Hall and Mariesse (1995), since we would lose too many observations by setting e.g. the lower limit to their suggested minimum limit of 90 percent. Similarly, we restricted observations to those with a growth or decline of sales smaller than 300 percent. Data have been cleaned further for obvious keypunch errors. For example, the values are replaced by adjacent values whenever there is a drop to zero (or missing) followed by a return to the value of previous year (e.g., 200,200,0,200), or a mistake in decimal value (6050,4550,60.5,45.5). We also lose some observations due to missing data in investment series over the entire analysis period and exclude state-owned firms. To this end, we have obtained unbalanced panels where we have information on exit, entry, and missing values of some variables of the firms as well.

2.2. DESCRIPTION OF THE DATASET

Our final data for the empirical analyses covers manufacturing firms with more than 19 employees for 2006-2015 period. As can be seen in Table 1, firms that are doing R&D (R&D investor firms) are quite smaller than those which do not (non-R&D firms). In other words, the number of non-R&D firms is considerably higher than those which are R&D investors.

Table 1: Distribution of the Dataset w.r.to R&D

Year	Non-R&D	R&D Investors	Total Number of Firms
2006	22.862	736	23.598
2007	21.669	853	22.522
2008	23.089	960	24.049
2009	20.910	1.113	22.023
2010	23.998	1.315	25.313
2011	28.244	1.438	29.682
2012	30.691	1.569	32.260
2013	33.078	1.536	34.614
2014	31.828	1.551	33.379
2015	32.072	1.477	33.549

2.3. SELECTION OF VARIABLES

2.3.1. Growth Variable

In this thesis we mainly try to shed light on the effect of the firms' R&D volatility on their growth performance. We use sales growth to represent firm growth. Particularly, it is the annual percentage growth in sales from the previous year which is calculated as follows:

$$GROWTH_{it} = {}^{Sales_{it}}/_{Sales_{it-1}} - 1 \qquad (2.1)$$

2.3.2. R&D Indicators and R&D Volatility

We construct the R&D volatility variable on firms' R&D expenditures from R&D Surveys dataset. In terms of R&D expenditures, we observe each firm's three-year R&D

behaviour [t – 2, t] over time and thus the volatility of R&D investment. A three-year period is set because, according to Griliches (1979), technological knowledge in the firm loses most of its value within three years after it is created (Van de Vrande et al., 2011; Argote, 1999). Values are measured during this three-year period to calculate how much the firms participate in the R&D activity and how much these R&D activities fluctuate (i.e. R&D volatility).

Below, equation (2.2) is used to calculate the level of R&D. Total expenditures on R&D investments, which is calculated over three-years, is divided up by the sum of revenues for three years to measure R&D intensity in order to check the effect of size (Kang, 2018).

$$Level\ R\&D_{i,t} = \frac{\sum_{t=T-2}^{T} R\&D\ Investment_{i,t}}{\sum_{t=T-2}^{T} Sales_{i,t}} \tag{2.2}$$

The following equation is used to calculate the volatility of R&D investment (Kang, 2018). It calculates the standard deviation of R&D investment over a three-year cycle to capture the change in the mean R&D investment over time. Since the magnitude of this metric rises with the amount of R&D, it is normalized by dividing it by the three-year mean R&D investment. The high measured values indicate that the R&D investment will be more volatile, otherwise persistent.

$$Volatility\ R\&D_{i,t} = \frac{\frac{\sum_{t=T-2}^{T}(R\&D\ Investment_{i,t} - \overline{R\&D\ Investment_{1}})^2}{2}}{\overline{R\&D\ Investment}_{t}} \tag{2.3}$$

Since it takes time for a firm's R&D activities to have an effect on firm growth, the lagged values of each variable are used in the estimations section. To put it another way, the effect of R&D activities from [t – 3, t – 1] on firm growth at period t is calculated. (Coad et al., 2016; Choi et al., 2016; Lee et al., 2014).

Table 2: R&D Level and R&D Volatility

Year	R&D Intensity Level	Volatility
2006	0,00164	2,58101
2007	0,00124	2,59400
2008	0,00138	2,42773
2009	0,00287	2,47114
2010	0,00193	2,77945
2011	0,00279	2,74469
2012	0,00241	2,80252
2013	0,00336	2,73386
2014	0,00310	2,68655
2015	0,00318	3,11019

According to the equations (2.2) and (2.3) written above, from year to year, the R&D intensity level and R&D volatility are presented in Table 2.

2.2.3. Control Variables and Descriptive Statistics

Number of employees, labour productivity, capital intensity, age, tangible assets volatility, intangible assets volatility, export status, foreign affiliation, and four-digit industry dummies are among the explanatory variables used in our two-stage estimation process (see Table 3 for definitions). These time-variant control variables are included in their lagged values to control for possible endogeneity in the estimations.

Table 3. Control Variables

Variables	Definitions/Sources
LP	Labour Productivity-Logarithm of value added per worker-AISS
Sales	Growth variable is calculated from sales of manufactured goods (deflated by 4-digit PPI)-AISS
Employee	Number of employees in logarithms-AISS
Capital Intensity	Logarithm of the capital stock over employees ratio-AISS
Foreign Affiliation	Dummy variable taking value 1 if firm's foreign capital share is greater than zero-AISS
Export Status	Dummy variable taking value 1 if firm exported-ATS
Intangible Assets Volatility (IA)	Standard deviation of the errors of the trend model of intangible investments
Tangible Assets Volatility (TA)	Standard deviation of the errors of the trend model of sum of physical investments of plant, property, and equipment
Age	Age of a firm in logarithms-SBS
Subsidy	Non-capital purchases of materials, supplies and equipment to support R&D

Sales is deflated by 4-digit producer price indices; employee is represented as number of employees in logarithms; foreign affiliation is represented as a dummy variable taking value 1 if firm's foreign capital share is greater than zero. Firm age is measured in terms of the market entry year.

For the analysis undertaken in this thesis, firm level productivity indicators are required. This is achieved by the standard labour productivity (LP), defined as value-added per employee where value added is gross output net of intermediate inputs. Output is measured as the sum of the revenues from the annual sales of the firm's final products, the revenues from the contract manufacturing and the value of stock of final products at the end of the year minus the value of stock of final products at the beginning of the year. It is deflated by using 4-digit producer price indices with the base year 2006.

As capital stock series of firms are not readily available in the data, we calculate them by applying perpetual inventory methodology using the series of investment for machinery and equipment, building and structures, transportation equipment, and computers and programming, respectively.[4] Assuming that firms are on their balanced growth the initial capital stock for any capital good of a firm is got by dividing the initial investment flow over the sum of growth rate of output and depreciation rate.[5] As for the firms reporting zero investment in the initial period it is presumed that they cannot be producing without capital. Therefore, their initial value of capital stock is computed where they report positive investment and iterated back to the starting year. After calculating capital stock series for building and structure, machinery and equipment, transportation equipment,

[4] Since the disaggregated investment deflator is not available, the different investment series of these capital goods are deflated by the aggregate investment deflator. The aggregate investment deflator used is provided by the Ministry of Development.

[5] Explicitly, denoting the initial year of the firm with zero the initial capital stock is constructed as follows: $K_1 = (1-\delta)K_0 + I_0$ (Equation 1), $\frac{K_1}{K_0} = (1-\delta) + \frac{I_0}{K_0}$ (equation 2). Since firms are at their balanced growth path, the growth rate of capital is equal to the growth rate of output $(1+g)$. We use the average annual growth rate of a firm for the years that it appears in the sample. From equation 2 the initial capital stock can be obtained as follows: $K_0 = I_0/(g+\delta)$. Following Özler and Yılmaz (2009), depreciation rates of 5%, 10%, 20% and 30% are used for building and structure, machinery and equipment, transportation equipment, computer, and programming respectively.

computer and programming, the series obtained are aggregated to compute the total capital stock series of the firm.

Firms provide a wide range of resources and capabilities, including tangible and intangible assets that include equipment, knowledge, know-how, and activities. We incorporate two additional variables as tangible investment volatility and intangible investment volatility in our analyses. Tangible investment volatility is the standard deviation of the errors of the trend model of sum of physical investments of plant, property, and equipment. Intangible investment volatility is the standard deviation of the errors of the trend model of intangible investments.

In our dataset, as firms are mainly classified into two groups of R&D performers and non-R&D performers, in Table 4 one can see the overall comparison of those groups in terms of the outcome and some control variables. In general, R&D investors perform better with respect to firms which do not invest in R&D.

Table 4: Descriptive Statistics w.r.to R&D Status

	Non-R&D	***R&D Investors***
Sales Growth (%)	7,147	9,928
Employee (mean in log)	4,192	6,073
LP (mean in log)	9,553	10,402
Capital Intensity (mean in log)	10,147	10,823
Age	7,050	10,230
Export Status	0,414	0,843
Foreign Affiliation	0,028	0,127
Intangible Investment	0,284	0,660

Particularly, the characterization of non-R&D and R&D investor firms show that R&D investor firms grow faster than non-R&D firms and are greater in size. A higher share of R&D investors invests in intangible assets, and they are more capital intensive. The results, which are compatible with the stylized facts reveal that the firms that make R&D

are exporting more and they are globally more integrated. In addition, R&D performers appear to be more productive and older than non-R&D performers.

2.4. METHODOLOGY

In some econometric studies, detrimental effects on the characteristics of traditional estimators such as least squares arise due to sample selection issues of non-random sampling. In other words, a common problem when using observational data is deviations from randomly selected samples where incidentally truncated dependent variables could occur. Selection problems can also be encountered when working with R&D performer firms. That is, if R&D firms are employed in a study such as ours, we could face with the risk of choosing a biased sample. Therefore, in this study, it would be appropriate to apply Heckman's two-step procedure in order to avoid the problem of selection bias (Heckman, 1979). Heckman's model is a method used to predict regression models that suffer from sample selection bias. The Heckman two-step method offers to control for selection by a probit model where individual characteristics are incorporated for the decision to participate (in R&D in our case) (Wolfolds and Siegel, 2018). Accordingly, the two-step Heckman method which is a correction method for selection bias basically consists of two equations. In order to the estimates to be consistent, the error terms and the relationship between these two equations must be specified correctly (Hussinger, 2008). In our case, two regressions are carried out on probability of investing in R&D and on the association between R&D volatility and firm growth.

Particularly, in our study which examines the relationship between R&D volatility and firm growth, firms that exhibit non-random R&D volatility can cause selection bias if the determinants of investing in R&D are associated with the error term. In other words, as R&D and non-R&D firms are not randomly selected, an example selection problem may arise when analysing growth performance of R&D firms. In order to overcome this problem, this study first takes into account the R&D decision of the firm from which the sample is selected. That is, the first stage is the selection equation that describes the factors affecting the probability that firm *i* will invest in R&D at time t where a probit model is utilized because the dependent variable is binary:

$$I_{i,t}^{*} = \beta x_{i,t} + \varepsilon_{i,t} \quad (2.4)$$

In this first stage equation, *i* represents the firm, t represents the year and $\varepsilon_{i,t}$ indicates the error term. If firm *i* makes R&D at time t, $I_{i,t}^{*}$ takes a value of 1; in contrast, if firm *i* does not make R&D at time t, $I_{i,t}^{*}$ takes a value of 0. The below equation represents the probability of being an R&D performer firm:

$$P(I_{i,t} = 1) = P(I_{i,t}^{*} > 0) = P(\varepsilon_{i,t} - \beta x_{i,t}) = \Phi(\beta x_{i,t}) \quad (2.5)$$

Thus, our final selection equation is as follows.

$$\mathrm{R\&D}_{i,t} = X_{i,t-1}\beta + +\upsilon_{i,t} \quad (2.6)$$

The cumulative distribution function of the standard normal distribution is assumed by the probit model. R&D is a binary variable that gets the value 1 if firm *i* invests in R&D in one form (i.e., has R&D expenditures greater than 0) in year t, and 0 otherwise. X is the vector of control variables representing labour productivity, capital intensity, age, intangible investment dummy, dummies of export status and foreign affiliation as well as subsidies and sectoral R&D intensity at four-digit industry level.

Taking into account all R&D and non-R&D firms in our dataset and performing maximum likelihood estimation (MLE), the Inverse Mills ratio (IMR) is calculated from the first stage equation in question. Depending on the predicted parameters, IMR is computed as the ratio of the probability distribution function to the cumulative distribution function of each observation.

The second stage equation is to analyse the impact of R&D volatility on firm growth. IMR from the first stage estimation is used as a control variable in the second stage. To control for unobserved, we assume that heterogeneity among firms fixed-effects regression is used at this stage.

$$\mathrm{GROWTH}_{\mathrm{i,t}} = \alpha R\&D_{it-1}^{Volatility} + \mathrm{X}_{\mathrm{it-1}}\gamma + \mathrm{Mills}_{\mathrm{it}} + \mathrm{e}_{\mathrm{i,t}} \quad (2.7)$$

Next, in order to deepen our analyses, we split our sample into the subsamples of four quartiles with respect to size distribution in terms of sales. Afterwards, we run annualized growth rates on our R&D indicators and a series of control variables using our two-step estimation methodology. With these estimations in subsamples instead of having the average effect of R&D volatility on the average firm; we try to reveal a more elaborated relationship between firm growth and R&D volatility. That is, by running regressions at various percentiles of the size distribution, we aim to gain a better understanding of the relationship in question.

CHAPTER 3

3. RESULTS

3.1. R&D VOLATILITY and FIRM GROWTH

As a first stage, we analyse the factors that increase the likelihood of firms to engage in R&D activities according to probit specifications. Table 5 documents the estimated coefficients on the variables that determine the probability of doing R&D for firms in the manufacturing sector. At a first glance, the coefficient for the lagged R&D variable is statistically significant and positive for manufacturer firms. Obviously, for firms that already participate in R&D activities, their capacity and likelihood to make and sustain R&D investments also increase.

One important feature in determining firms' R&D behaviour is size. Due to scale advantages and financial competencies, size in terms of employment affect R&D investments positively (Gault 2010). In parallel with the literature, we reveal that the bigger the firm, the greater the odds of making R&D investments. As an indicator of internationalization, we observe that exporting and foreign ownership increases the possibility of firms to make R&D. The positive effect of exports on R&D is well known, thanks to its learning effects (Damijan et al., 2010). According to Girma et al. (2008), in terms of foreign affiliation, current research reveals that foreign colleagues of domestic firms support their subsidiaries' R&D efforts, facilitate access to finance and increase efficiency by transferring their knowledge to domestic firms. We further observe that the investment factor in intangible investments is effective for the R&D decision of firms in the manufacturing sector.

Table 5: R&D Selection Equation

	R&D Decision
R&D (t-1)	0.9347*** (0.000)
LP (t-1)	0.1376*** (0.000)
Employee (t-1)	0.0029*** (0.000)
Capital Intensity (t-1)	0.0055** (0.021)
Foreign Affiliation (t-1)	0.1743*** (0.001)
Export Status (t-1)	0.1169*** (0.003)
Age	-0.0034 (0.109)
Subsidy (t-1)	0.0628* (0.074)
Intangible Investment (t-1)	0.0759*** (0.000)
Sectoral R&D Intensity	0.111 (0.272)
Log-likelihood	-7256.241
Observations	196937

Notes: Probit regression. A dependent variable is a binary variable that takes the value of 1 if the firm had R&D expenditure in year t and, 0 otherwise. Two-digit sector and year dummies are included. Reported are the estimated regression coefficients and p-values (in parentheses). Asterisks indicate levels of significance (***: p < 1%; **: p<5%; *: p<10%).

We find that labor productivity is strongly related to R&D behaviour. Unsurprisingly, the capital intensity which is expected as an important firm-specific characteristic that influences a firm's decision to invest in R&D is found to be closely linked to the probability of doing R&D. The assumption that capital intensity raises the possibility of firms doing research and development operations is a strongly supported fact in the related literature (Galende and Suárez, 1999). Subsidies from national sources seem to be effective for manufacturing firms. Subsidies are a triggering factor to make R&D decisions, while they subsidy ease the potential liquidity pressures for firms (Lach, 2002).

Table 6: Sales Growth Corrected for Sample Selection

	Sales Growth		
	(1)	**(2)**	**(3)**
R&D Intensity Level (t-1)	0.2644***	0.2581***	0.2718***
	(0.000)	(0.000)	(0.000)
Volatility (t-1)	0.0551*	0.0519*	0.0437*
	(0.087)	(0.074)	(0.081)
R&D Volatility * R&D Intensity (t-1)		0.0963**	0.0919**
		(0.021)	(0.019)
IA Volatility (t-1)			0.0077
			(0.536)
TA Volatility (t-1)			0.0018
			(0.297)
IA Volatility * R&D Volatility (t-1)			0.0012
			(0.126)
TA Volatility * R&D Volatility (t-1)			0.0291**
			(0.045)
LP (t-1)	0.2341***	0.2555***	0.2007***
	(0.000)	(0.000)	(0.000)
Employee (t-1)	0.0184***	0.0162***	0.0170***
	(0.000)	(0.000)	(0.000)
Capital Intensity (t-1)	0.0087	0.0095	0.0089
	(0.123)	(0.222)	(0.149)
Foreign Affiliation (t-1)	0.0009***	0.0006***	0.0006***
	(0.007)	(0.001)	(0.008)
Export Status (t-1)	0.0036***	0.0038***	0.0025***
	(0.000)	(0.002)	(0.001)
Age	-0.1671***	-0.1533***	-0.1248***
	(0.000)	(0.000)	(0.000)
Inverse Mills Ratio	-0.98***	-0.96***	-1.01**
	(0009)	(0.009)	(0.012)
R-squared	0.017	0.017	0.019
Observations	11322	11322	11322

Notes: All models include year and firm fixed effects. Reported are the estimated regression coefficients and p-values (in parentheses). Asterisks indicate levels of significance (***: p < 1%; **: p<5%; *: p<10%).

In Table 6 we present the second step estimations in Heckman's procedure to show the relationship between R&D volatility and firm growth. We have three different specifications and irrespective of the equation, we find past R&D activity affect firm growth positively. This is consistent with endogenous growth theories, which express R&D efforts as a key component of firm growth (Grossman and Helpman 1991). We find that the higher the firm size the higher is the growth performance. This finding is parallel with the majority of existing literature rejecting Gibrat's law. We observe that age is statistically significant but negatively related to firm growth. According to Coad and Rao (2010) and Coad et al. (2013), the age of a firm has an effect on its growth, but it may have a contradictory effect arguing that firms grow more when they are younger since they reach their effective size over time, and they have less bureaucracy and more organizational flexibility in their decision-making process compared to older firms. In addition, younger firms can reap high profits if their R&D investments are successful and react quickly to changes (Kang, 2018). As expected, and can be seen further seen from all the estimation results in Table 6, labor productivity, export status, and foreign affiliation are significantly and positively related to firm growth. While the positive relationship between productivity and growth is well established in the related literature, as an indicator of internationalization, the positive effect of exports on sales growth is explained with learning effects (Damijan et al. 2010; Dalgıç and Fazlıoğlu, 2021). In terms of foreign affiliation, the related literature reveals that foreign colleagues of domestic firms facilitate access to finance, support their subsidiaries' R&D efforts, and hence increase firm growth by transferring their knowledge to domestic firms (Girma et al. 2008).

In contrast to the findings from vast literature, we show that R&D volatility has a positive and statistically significant effect on firm growth for the Turkish manufacturing industry. This result might suggest that firms' R&D expenditure volatility is an indicator of the aggressive and proactive management of R&D. That is while R&D volatility can be considered as a measure of proactive R&D management. Firms inherently move between exploration and exploitation of R&D, and this may result in a highly volatile R&D spending situation with a positive impact on firm growth.

Just as the related literature reveals that increasing investment in R&D is an important factor for a firm's long-term performance, recent studies have started to question the importance of R&D volatility and proactive R&D management (Mudambi and Swift, 2011; 2014; Swift, 2013). Volatility in R&D investments encourages discipline by halting unnecessary R&D projects, thereby increasing internal competition for the R&D budget and allowing firms to shift their focus from exploration to exploitation. In essence, it is argued that the necessary fluctuations/changes in R&D expenditures, which are persistent and habitual, are associated with higher and healthier firm growth (Mudambi and Swift, 2014).

There exist some studies supporting these arguments. For instance, Di Masi et al. (2003) indicate that when a firm moves sequentially from exploration to exploitation, a relatively unpredictable R&D expenditure profile (i.e. volatility) should be observed over time. Firms that make the most appropriate adjustments in their R&D expenditures (portfolios) exhibit higher firm growth than those that do not make these adjustments. To put it more clearly, firms that do not manage the transitions between exploration and exploitation very well cannot exhibit good performance in terms of growth. Therefore, volatility of R&D expenditure is positively linked to firm growth. Further, in order to be successful, firms need to provide experience and knowledge management systems that allow them to step in the right direction at the right time to effectively switch between cycles of exploration and exploitation (Mudambi and Swift, 2011). These intangible assets are the hidden treasures within the firm. Penrose (1959) states that these assets, which give the firms competitive capabilities, cannot be divided and used profitably outside the firm for firms which are highly specialized and have valuable resources/assets. For this reason, it becomes a driving force for firms in their expansion strategies (Teece, 1982, 1986; Wernerfelt, 1984; Montgomery, 1994). If firms are successful in proactive management of R&D spending, they have higher growth rates (Penrose, 1959; Marris, 1964; Mahoney and Pandian, 1992).

In Table 6, we observe a significantly positive relationship between firm growth and R&D intensity level which is measured over a three-year time span. There exist several studies in the literature finding such positive association between R&D intensity and firm performance (Jaffe, 1986; Cockburn and Griliches, 1988; Morck and Yeung, 1991; Lev and Sougiannis, 1996; Hall et al., 2005). In Table 6, in the second and third equations, we further interact the variable of R&D intensity level referring to the volume of R&D with our R&D volatility variable. The positively significant coefficient on this interaction term suggests that the higher the volume of R&D within a firm the larger the impact of R&D volatility on firm growth. That is suggesting economies of scale in R&D investments, higher R&D intensity boosts the positive growth effect of volatility in R&D.

In the last column of Table 6, we provide evidence on the relationship between R&D volatility and intangible/tangible asset volatility which must be considered as factors to complement the association between R&D volatility and firm growth. This is motivated by the fact that R&D fluctuation also occurs with the accumulation of stocks of tangible or intangible factors owned or controlled by a firm (Amit and Schoemaker, 1993). High tangible/intangible asset volatility generally signifies that the firm adds new assets on top of the old assets; while low tangible/intangible asset volatility generally signifies that the firm uses existing (older) tangible assets to maximize profits from R&D volatility (Souder and Bromiley, 2012; Patel et al., 2017). Accordingly, we ask the following question of "are tangible and intangible assets enablers for R&D volatility?" and "is it necessary to support proactive R&D investments with proactive investments in tangible and intangible assets?". We look for answers to these questions in line with the relevant literature assuming that there must be volatility in those assets (tangible and intangible) along with the volatility in R&D investments. We hypothesize that tangible and intangible asset investments can help improve the role of R&D investments, and with a higher degree of tangible/intangible asset volatility, the connection between R&D volatility and firm growth is more pronounced.

In terms of intangible assets volatility, we find an insignificant coefficient on the interaction term of this variable with our R&D volatility measure. Whereas the accumulation of complex intangible resources is a process that carries over a long term, it might be difficult in the short term to play a complementary role for the returns on R&D

volatility. The last column of Table 6 also provides the estimation result including the interaction between tangible asset volatility and R&D volatility. This result indicates that as R&D volatility increases, a higher degree of tangible assets volatility enhances firm performance. That is, we provide evidence that the volatility of tangible assets reinforces the connection between R&D volatility and sales growth.

3.2. ESTIMATION RESULTS AT DIFFERENT SIZE QUANTILES

Results at different quantiles of size distribution are provided in Table 7 where we only display the findings from second stage estimations. For these estimations, our sample is divided into four quantiles as regards size distribution in terms of sales in order to elaborate whether R&D volatility and firm performance vary with firm size. While the first quartile contains the smallest 25% of firms, and the fourth quartile contains the largest 25% of firms. Afterward the described specification in section 4.4. is estimated once for each quartile.

Table 7: Sub-sample Analysis: R&D Volatility and Firm Growth by Firm size (Corrected for Sample Selection)

	Smallest Quartile	Quartile 2	Quartile 3	Largest Quartile
R&D Intensity Level (t-1)	0.0136	0.1061	0.2476***	0.2791***
	(0.1267)	(0.1013)	(0.000)	(0.000)
R&D Volatility (t-1)	-0.054	-0.042	0.0712***	0.0934***
	(0.111)	(0.234)	(0.000)	(0.000)
R&D Volatility * R&D Intensity (t-1)	0.0368	0.0752*	0.0999***	0.0842**
	(0.192)	(0.081)	(0.000)	(0.027)
IA Volatility (t-1)	-0.0006	0.0042	0.0071	0.0084**
	(0.412)	(0.541)	(0.197)	(0.039)
TA Volatility (t-1)	-0.0005	-0.0009	0.0021	0.0015
	(0.232)	(0.313)	(0.181)	(0.272)
IA Volatility * R&D Volatility (t-1)	0.0009	0.0001	0.0011*	0.0015*
	(0.151)	(0.239)	(0.091)	(0.089)
TA Volatility * R&D Volatility (t-1)	-0.0001	0.0007	0.0303*	0.0271**
	(0.166)	(0.142)	(0.086)	(0.069)
Inverse Mills Ratio	-0.88*	-0.81**	-0.91**	-0.90**
	(0.011)	(0.013)	(0.024)	(0.031)
R-squared	0.011	0.015	0.016	0.016
Observations	2831	2831	2830	2830

Notes: All models include year and firm fixed effects. Reported are the estimated regression coefficients and p-values (in parentheses). Asterisks indicate levels of significance (***: p < 1%; **: p<5%; *: p<10%).

Our findings suggest that the relationship between R&D expenditure volatility and firm growth is negative but not statistically significant in the two smallest quartiles while it positive and statistically significant in the two largest quartiles. This indicates that firm growth is positively related to R&D volatility, for larger firms in the Turkish manufacturing industry. That is R&D volatility increases the growth rate of firms only after a certain firm size threshold is reached. This finding is also valid for past R&D experience where we only find positively significant coefficients at the largest two quartiles of sales distribution. These results indicate that larger firms with proactive R&D management can develop better R&D strategies, and thus are better at successful innovations promoting firm growth via investing more effectively in R&D. On the other hand, small-scale firms are estimated to have a poor association between R&D volatility and firm growth. These results might also be attributed to the successful competitive power of large firms, with larger capital intensity, strong foreign affiliation (internationalization), and well-organized governance power. Overall, we show that the asymmetries arise between differently scaled firms due to the inherent uncertainty of R&D.

In terms of tangible and intangible assets volatility, we reveal that volatility regarding investments amplifies the positive effect of proactive R&D on the growth performance of firms at the highest two quantiles. That is, the interaction terms of tangible and intangible asset volatilities with our R&D volatility variable are significant only for larger firms. Since the firm's assets grow in proportion to its size, it is understandable that uncertainty will emerge due to the essence of R&D. On the other side, the R&D fluctuation requires that the firm should use the proactive management method as including its intangible assets in the production process (Villalonga, 2004). Accordingly, intangible asset volatility together with R&D volatility may boost firm performance much further. That is, if proactive R&D investments are completed with intangible asset volatility, firms’ growth performance can be much better. As for the volatility of the tangible asset, if the firm has low tangible asset volatility, this may limit the gains from R&D volatility. This is because the company may lack the complementary capital needed to fulfil the manufacturing requirements of new goods. While capital sizes are much larger for larger firms it is not surprising that as tangible asset volatility rises the positive impact of R&D volatility on firm growth increases.

From a different perspective, there are some arguments in the related literature explaining that there is more R&D volatility in large firms. First of all, small firms, which are generally entrepreneurs, consist of single business units (Reinganum, 1983). Smaller firms do not have multi-department organizational structures due to the fact that they have not reached sufficient size (Mudambi and Swift, 2011). Moreover, smaller firms do not have "facilitating resources" and "slack resources” and thus it is more difficult for small firms to make exploration and exploitation (Lubatkin et al., 2006). As firm size increases, the absorption capacity of firms increases, and firms are both more capable of making exploration for new knowledge and, making it easier to benefit from their existing experiences and capabilities (Köğüt, 1991; Zahra and George, 2002; Hernan et al., 2003).

In conclusion, size is an important feature in determining the R&D behaviour and gains from R&D. An important reason for this is the existence of scale advantages. Due to the existence of such advantages, financial capabilities are complete and human capital is more concentrated in R&D activities to make proactive investments in R&D with more benefits.

CONCLUSION

Understanding the heterogeneity of R&D routines is critical to understand differences in the growth performances of firms. Many studies prove that R&D activities are substantial for firm growth. The majority of these studies concentrate on the R&D level where increasing R&D expenditures has beneficial consequences. This study takes one step ahead for Turkey and draws attention to the relationship between R&D expenditure volatility and firm growth.

Our results suggest that firms with volatile R&D expenditures have better growth performance. The ability to identify and terminate underperforming R&D projects and the transition between exploration and exploitation require high technological capabilities where proactive R&D management is the most important way for firms to realize creative destruction. Our findings support this Schumpeterian view and put forward that firms with highly fluctuating R&D expenditures are those with proactive R&D management benefiting more from their R&D investments. That is, firms with higher R&D volatility might have the power to effectively monitor R&D projects. Since this observed volatility is suggestive for proactive R&D management, high levels of R&D expenditure volatility might lead to better rates of creation of knowledge, innovation, and firm performance for Turkish manufacturing firms. The findings of the study reveal that volatility for R&D expenditures is an argument that should be considered in the evaluation process of R&D activities both by researchers and policymakers. It is important to conduct R&D activities from a long-term perspective and to define strategies that are transitional between exploitation and exploration which allows healthy R&D activities rather than monotonous and useless R&D.

We investigate firms at different quantiles of size distribution and our results further reveal that tangible and intangible assets volatility amplify the positive effect of proactive R&D on the growth performance of firms at the highest quantiles. This suggests that as higher tangible and intangible asset volatility indicates higher production flexibility, larger manufacturing firms that can proactively evaluate and manage their tangible and intangible asset stocks can raise benefits from R&D volatility over time. Our investigation at different quantiles of size distribution further reveals that R&D volatility increases the growth rate of firms only after a certain firm size threshold is reached. This finding indicates that larger manufacturing firms with proactive R&D management can develop better R&D strategies, and thus are better at successful innovations promoting firm growth via investing more effectively in R&D. Competitive advantage of larger firms with higher capital intensity, strong foreign affiliation, and well-organized governance power might also be linked to our outcomes.

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APPENDIX 1. ETHICS COMMISSION FORM

APPENDIX 2. ORIGINALITY REPORT