Firm Growth and Total Factor Productivity: A Methodology for Examining the Size Controversy

Tarek Eldomiaty*
School of Business, The American University in Cairo, Egypt
Marina Apaydin
School of Business, The American University in Cairo, Egypt
Jasmine Fouad
School of Business, The American University in Cairo, Egypt
Marwa Anwar
Misr International University, Egypt
Heba El Zahed
Misr International University, Egypt

Abstract

This paper examines the significance and robustness of four measures of growth of the firm with respect to firm-level Total Factor Productivity (hereinafter TFP). These four measures are (a) growth of total assets, (b) growth of sales, (c) growth of fixed assets, and (d) weighted growth of fixed assets. The four measures are examined in the business and economics literature in different contexts. The results of related studies do not include a consensus regarding the validity of a certain measure. The ultimate objective of this paper is to present a realistic view of growth of the firm.The data used in this paper represent the non-financial firms listed on DJIA30 and NASDAQ100. These data were obtained from Reuters Finance database© (https://www.reuters.com/markets/) and cover the quarterly periods from June 1992 till March 2018The results of the robustness test show that (a) firm-level TFP is positively associated with weighted growth of fixed assets, (b) the estimates of weighted growth of fixed assets are robust which is an indication to the intrinsic relationship with firm-level TFP, (c) the significance of weighted growth of fixed assets varies across industries which reflects an industry effect. This paper contributes to the related literature by examining the robustness of the common measures of growth of the firm. As far as growth of the firm and size are exchangeable, the lack of conformity in the literature raises a controversy regarding the search for a reliable measure of size and growth of the firm.

Keywords: Growth of The Firm, Size of The Firm, Firm-Level Total Factor Productivity, Robustness, Growth of Total Assets, Growth of Sales, Growth of Fixed Assets, Weighted Growth of Fixed Assets

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* Corresponding Author
Email: tarek_eldomiaty@aucegypt.edu
Address: The American University in Cairo, School of Business

1. Introduction

Throughout the evolution and development of the theory of the firm, the issues related to the growth have been controversial due to the diverse measures of growth such as growth of fixed assets, growth of total assets, and growth of sales revenue. The authors believe that a comprehensive understanding of the growth of the firm requires an integrated view incorporating the elements of both balance sheet and income statement. This issue has been treated from a measurement point of view, the most notable is presented by Kim and Schmidt (2008). In addition, measures of growth of the firm are used as proxies for the size of the firm which is a critical variable in a variety of business studies. The size effect is often observed when examining a wide range of issues in finance as well as microeconomic studies (Biesebroeck, 2005, 2007; Zvi and Mairesse, 1983; Söderbom and Teal, 2004; Clancy and Román, 2013; Antonelli and Scellato, 2013). Therefore, the quest to resolve inconsistencies among different measures of growth of the firm is a long time due.

This paper offers an epistemologically robust examination of four different measures of the growth of the firm. Several empirical studies have concluded that the size and growth of the firm may not be interchangeable. In fact, the size-growth theory clearly differentiates between size and growth (Almus and Nerlinger, 2000; Audretsch et al., 1999; Bechetti and Trovato, 2002; Dunne and Hughes, 1994; Dunne et al., 1989; Evans, 1987; Goddard et al., 2002; Hall, 1987; Hart and Oulton, 1996; Weiss, 1998). Nevertheless, studies in finance continue to use measures of firm size and growth interchangeably (Handa, et al., 1989; Weinberg, 1994). Logically, a positive change in the size of the firm is an implicit result of its growth. This argument is worth further empirical examination.;

1.1. Objectives

The objective of this paper is to examine the validity and robustness of four different measures of growth of the firm and productivity. The latter is conveniently measured by firm-level TFP.

1.2. Hypotheses

The authors propose the following hypotheses as cited in the related literature.

H1: A significant association exists between the growth rate of fixed assets and Total Factor Productivity.

H2: A significant association exists between the growth rate of total assets and Total Factor Productivity.

H3: A significant association exists between growth rate of sales and Total Factor Productivity

H4: A significant association exists between weighted growth of fixed assets and Total Factor Productivity.

1.3. Contribution

As far as measures of growth of the firms are interchangeable, this paper offers empirical examination of the robust measure of growth, thus helping clear out a controversy about Size-Growth relationship.

The rest of the paper is organized as follows. The first section provides an overview of the growth of the firm and its productivity. The second section presents data and methodology. The third section discusses the statistical tests and estimation. The last section concludes.

2. An overview of the growth of the firm and its productivity

High-growth firms are strategically important for national economies (Du and Temouri, 2015). Gupta, et al., (2013) conclude that there exist two opposing views. First, a believe that the growth is predictable. Second, growth is unpredictable and opportunistic. Navaretti, et al., (2014) highlight that young and fast-growing firms contribute to the growth of the economy and their growth is a significant topic in contemporary research. Segara and Teruel (2014) mention that the European Commission supports the advancement of high-growth firms, especially in countries that are economically disadvantaged and that have weak potential for creating job opportunities. In this sense, a firm's production function is considered a fundamental variable (Sickles, and Zelenyuk, 2019; Saari, 2006; Thompson, 1981; Goswami, et al., 2019). The post 2008 financial crisis caused disruptions and decline to the growth of firms (Malinić, et al., 2020; Queirós, et al., 2019). However, high growth rates are not always sustainable (Scherer, 2001).

2.1. Growth of the Firm

Achtenhagen, et al. (2010) and Gruenwald (2015) state that turnover and sales measures are used by about 50% of empirical studies, whereas almost 30% of studies use employee growth, both in America and Europe. LaDue (1997) indicates that financial measures of size include net worth of the firm, which indicates a drawback. That is, changes in net worth do not reflect changes in assets and/or liabilities. Thus, although the firm could have improved its income position, it will not be reflected in the growth rate being calculated using the net worth. In addition, LaDue (1977) further indicates that both output-based and input-based measures of the firm size have the same drawback of failing to distinguish between productive and unproductive growth. That is, output measures of the size such as gross sales can provide an inaccurate measure of growth, since gross sales can be confounded by other variables such as cyclical changes in commodity prices. In sum, the measurement of growth is complex and requires more complicated configurations of performance measurement (Beers and Zand, 2014).

2.2. Firm-level Total Factor Productivity

Šajdlerová et al., (2020) and Tiruvengadam, et al. (2021) offer an empiricism of TFP being efforts made to maximize output while simultaneously minimizing inputs. Botrić, et al. (2017) emphasize that research on TFP is often focused on the enhancements of the whole economy, while

literature concerning industries and individual firms is less common. However, the increasing accessibility of firm-level data has allowed researchers to examine firm-level TFP as a key determinant of aggregate productivity. That is, scholars prefer using TFP due to the ability to well reflect the relation between output and input. Giovannini and Nezu (2001) show that TFP can be measured using either index number approaches or estimation-based methods. For instance, Francis, et al. (2020) estimated TFP at the firm level using Cobb and Douglas (1928) production function.

2.3. The Nexus Between Productivity and Growth of the Firm

The theory of growth of the firm foresees production efficiency, financial status, and profitability as the principal to reach a significant level of growth (Ponikvar, et al., 2009), but only a few firms are capable of maintaining a sustainable high-rate growth (Delmar et al., 2003). Du and Temouri (2015) found that a faster TFP growth in a past period significantly increases the chances of experiencing a high-growth pattern in the following period in services and manufacturing firms in the UK. However, Goswami et al. (2019) argue that empirical research has struggled to identify a strong relationship between growth of the firm and its productivity. For instance, using data from Spain, Italy, France, and the UK, Bianchini et al. (2017) conclude that there is no evidence that firms that are experiencing persistent high-growth rates are more productive or profitable. This negative association is further supported by Goswami, et al (2019) as they indicate that the relationship between firms' financial conditions and growth in Ethiopia and Hungary aren't the same when compared with Turkey and Côte d'Ivoire. Nevertheless, an early discussion of the nexus between productivity and growth (Penrose 1959) suggests that the growth of the firm may cause a decline in productivity. That is, Ocasio and Joseph, (2018) claim that managerial duties may distract managers from monitoring and minimizing operating costs.

2.4. Reasons Behind the Diversity between Productivity and Growth of the Firm

Goswami, et al., (2019) illustrate that the negative relationship between productivity and firm growth might be a result of measurement issues given that the data concerning firm-level prices are rarely available. In addition, TFP is usually measured using revenue which is known as revenue-based TFP (TFPR) and not in quantity terms which is known as quantity-based TFP (TFPQ). Thus, firms that charge higher prices may seem to be more productive based on TFPR, which doesn't represent technical efficiency. Cabral (2007) argues that market structure, notably the lack of competition, is a plausible interpretation. Moreover, Coad (2007, 2009) illustrates that firms might be more productive by downsizing, instead of increasing output (Daunfeldt, et al., 2010).

3. Data, Variables and Statistical Estimation

This section includes the empirical analysis of the relationship between TFP and four different measures of growth of the firm. The empirical analysis is preceded by standard statistical tests to adjust the measurement of data.

3.1. Data

The data used in this paper represent the non-financial firms listed at DJIA30 and NASDAQ100. The data are obtained from Reuters Finance database© (https://www.reuters.com/markets/). The data covers the quarterly periods from June 1992 to March 2018.

3.2. Variables

The variables being examined in this paper are as follows.

Dependent variable: The paper examines the growth rate of TFP as first difference ΔTFP.

Independent Variables: The independent variables include four different measures of growth of the firm that have been examined in the literature across diverse topics. The four measure are (a) the Weighted Growth of Fixed Assets $\Delta WGFA$, Growth Rate of Fixed Assets ΔGFA, Growth Rate of Sales ΔGS, and Growth Rate of Total Assets ΔGTA. The four measures are examined as the first difference as well. Control variables are also included to capture the industry effects. Table (1) shows the main references that have examined the variables under consideration.

Table 1. Variables examined in the paper.

Variable	Main References
Total Factor Productivity TFP (being measured as internally imputed) = Costs of Employees + EBITDA$_t$	Marschak and Andrews, 1944; Olley and Pakes, 1996; Ackerberg et al., 2015; Francis, et al. 2020; Niu et .al, 2021; İmrohoroğlu and Tüzel, 2014
$\text{Weighted Growth of Fixed Assets} = \ln\left(\frac{FA_t}{FA_{t-1}}\right)\frac{Sales_t}{\text{Max Sales}}$	Eldomiaty (2010), Eldomiaty and Rashwan, 2013; Eldomiaty et al., 2019
$\text{Growth Rate of Fixed Assets} = \ln\left(\frac{FA_t}{FA_{t-1}}\right)$	Avarmaa, et al., (2013); Okwo et al., (2012); Peterson, (2002); Titman et al., (2004).
$\text{Growth Rate of Sales Revenue} = \ln\left(\frac{S_t}{S_{t-1}}\right)$	Davidsson and Wiklund, (2000); Ponikvar et al., (2009).
$\text{Growth Rate of Total Assets} = \ln\left(\frac{TA_t}{TA_{t-1}}\right)$	Yao et al. (2011) ; Sougiannis, et al., (2008)

3.3. How Different the Measures of Firm Growth are?

As far as the four measures of firm growth differ in terms of components, the standard research treatment requires an examination of the scale of these differences using skewness (Doane, and Seward, 2011). The data is arranged in ascending order, then is divided into four quartiles. The 1st quartile denotes the lowest growth, and the 4th quartile denotes the highest growth. The results are reported in Table (2).

Table 2. The Skewness of Measures of Growth of the Firm

Measures	Skewness of Q1	Skewness of Q2	Skewness of Q3	Skewness of Q4
Weighted Growth of Fixed Assets	-20.548	1.528	0.305	6.941
Growth of Fixed Assets	-10.891	1.646	0.261	5.407
Growth of Sales Revenue	-5.607	0.726	0.124	5.844
Growth of Total Assets	-7.371	1.258	0.2016	5.077

The results reported in table (2) show that the four measures of growth of the firm don't have the same trend. As further scrutiny, the authors tested the significance between the four measures apart from being classified into groups. The Friedman test (Friedman, 1937, 1939, 1940) hypothesizes that; H0: Groups are similar, H1: Groups are different.

The results of Friedman test show that the four measures firm growth differ significantly at 1% significance level [N = 4, Chi-Square Stat. (df) = 12. 00 (3)] rendering the issue of growth of the firm controversial empirically. The estimation equation takes the form of nonlinear model Least Squares Dummy Variables (LSDV) that follows.The estimation equation takes the form of nonlinear model Least Squares Dummy Variables (LSDV) that follows.

$\mathbf{y}_{tk} = \alpha_k + \sum_{i=1}^{k} \beta_{ik} \mathbf{X}^3_{itk} + \lambda_k + \upsilon_{tk}$,Where t = 1, …..,n, k = number of firms in each group, $\mathbf{y}_{tk}$ = First different of TFP (ΔTFP), $\mathbf{x}_{itk}$ = Four different measures of Growth of the Firm (being measured as first difference as well), λ_k = Random error term due to the individual effect, υ_{tk} = Random error.

4. Results and Discussion

This section includes the empirical results of the tests about the impact of growth of the firm on TFP.

4.1. The Association between Total Factors Productivity and Measures of Growth of the Firm

This section examines the separate associations between every measure of growth of the firm and TFP. The results are reported in table (3).

The dependent variable is ΔTFP. Independent variables are four measures of growth of the firm. Total panel (balanced) observations: 12,584. The RESET test (Ramsey, 1969; Thursby and Schmidt, 1977; Thursby, 1979; Sapra, 2005; Wooldridge, 2006). The data for the ΔGFA and ΔGTA fit the linear assumption [F (2, 12584) = 0.0056; F (2, 12584) = 0.0106 respectively]. The data for $\Delta WGFA$ and ΔGS fit nonlinear assumption, [F (2, 12584) = 4.905*; F (2, 12584) = 4.428** respectively] thus treated in cubic form to maintain the trend of the raw data. The data went through testing for the panel cointegration across different firms. The results of a Unit Root test (Dickey and Fuller, 1979, 1981; Pedroni,1999, 2004) show that a cointegration exists for each variable across the different firms. The Test Statistic (P-value) are as follows. $\Delta TFP = -56.5299\ (0.00)$, $\Delta WGFA = -63.1112\ (0.00)$, $\Delta GFA = -61.8643\ (0.00)$,

$\Delta GS = -55.3869\ (0.00)$, $\Delta GTA = -60.7965\ (0.00)$. This is a plausible indication of the consistency of each measure of growth across different firms. In addition, the Test Statistic (P-value) of a cointegration test using Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue) are as follows. None = 31344 (0.00), At most 1 = 3990 (0.00), At most 2 = 2576 (0.00), At most 3 = 3741 (0.00), At most 4 = 27308 (0.00). The results show that the four measures of growth of the firm are relevant to the TFP. The Hausman test for the Random Vs Fixed Effects show that $\Delta WGFA$ and ΔGFA are subject to Random Effects, while ΔGS and ΔGTA are subject to Fixed effects. The χ^2 Statistic (DF, P-value) are as follows. $\Delta WGFA = 0.073787(1, 0.7859)$, $\Delta GFA = 0.171646\ (1, 0.6787)$, $\Delta GS = 4.572048(1, 0.0325)$, $\Delta GTA = 9.230054(1, 0.0024)$. The estimation process uses Swamy and Arora estimator of component variances. The periods included = 104. The Cross-sections included = 121. T-statistics are reported between parentheses.

Table 3. The Results for the Effects of Measures of Firm Growth on Observed Total Factor Productivity

Variables	$\Delta WGFA^{*}$	ΔGFA^{*}	ΔGS^{**}	ΔGTA^{**}
Constant	0.000172 (0.0060)	-0.0000863 (-0.0030)	-0.0000885 (-0.0031)	-0.000102 (-0.0036)
Estimated Coefficient	0.0047 (2.794) ***	-0.0710 (-0.1840)	-0.019998 (-0.0646)	-0.276025 (-0.4656)
Period random (SD; Rho)	0.035874; 0.0001	0.033333; 0.0001	Period fixed (dummy variables)	Period fixed (dummy variables)
Idiosyncratic random (SD; Rho)	3.151878; 0.9999	3.152867; 0.9999		
Dummy Variables (Industry Effects)	Vary significantly across industries. Number of industry classifications = 42			
$\bar{R}^2$	0.0541%	-0.0077%	-0.0037%	-0.002%
S.E. of regression	3.151762	3.152763	3.152873	3.152846
F-statistic	7.809***	0.033864	0.995557	0.997619
Durbin-Watson stat	3.027	3.027985	3.028664	3.028608

* The method of estimation is Panel EGLS (Period random effects). ** The method of estimation is Panel Fixed Effects.
*** Significant at 1%

The results reported in table (3) show that the estimate of the Weighted Growth of Fixed Assets $\Delta WGFA$ is the only significant estimate and is associated with the highest explanatory power. The positive estimate indicates that firm-level TFP is positively associated with growth of fixed assets and growth of sales relatively. This result indicates the significance of learning by doing (Geylani and Stefanou, 2013; Du and Temouri, 2015; Bravo-Biosca, 2011). Nevertheless, in light of less conformity of the results, a test for the robustness of the four measures of growth of firm-level TFP is necessary.

4.2. Testing the Robustness of Firm Growth and TFP

This section aims at examining the sensitivity of firms' cross-sectional TFP. For this purpose, the authors constructed an index of TFP for all firms under consideration. The index is constructed as an equally weighted average index that covers the quarterly periods from June 30, 1992, to March 30, 2018. This index offers an opportunity to examine the extent to which firm-level TFP is sensitive to the entire firms in the index.

Table 4. The Results for the Sensitivity of Firms' TFP to the Index

Variables	ΔWGFA [I]			ΔGFA [I]			ΔGS [II]			ΔGTA [II]		
	β >1	β <1	-ve β	β >1	β <1	-ve β	β >1	β <1	-ve β	β >1	β <1	-ve β
Constant	-0.006	-0.001	0.007	-0.006	-0.001	0.007	-0.004	-0.001	0.008	-0.006	-0.002	0.007
Estimated Coefficient	-0.003 (-7.3) ***	0.0004 (1.63)	0.007 (37.85) ***	-0.40 (-1.8) *	0.04 (2.13) **	0.11 (0.77)	1.45 (1.46)	0.94 (1.16)	-1.63 (-3.89) ***	-0.51 (-0.87)	0.082 (1.54)	0.285 (1.06)
Dummy Variables (Industry Effects)	Vary significantly across industries											
N	3025	5837	3721	3025	5837	3721	3025	5837	3721	3025	5837	3721
$\bar{R}^2$	0.0006	0.0009	0.0008	0.00007	0.001	0.004	0.01	0.006	0.001	-0.0002	0.001	-0.0002
S.E. of regression	1.641	0.098	5.6	1.643	0.098	5.6	1.63	0.098	5.6	1.644	0.098	5.6
F-statistic	2.93**	6.74***	4.31**	1.21	6.37***	0.007	43.65***	37.98***	4.12**	0.95	5.34**	0.02
Durbin-Watson stat	2.93	2.77	2.99	2.93	2.77	2.99	2.93	2.78	2.99	2.93	2.77	2.99

Dependent variable is ΔTFP. Method of estimation is LS adjusted with White heteroskedasticity-consistent standard errors and covariance.

I The method of estimation is Panel EGLS (Period random effects). II The method of estimation is Panel Fixed Effects. *** Significant at 1%, ** Significant at 5%, * Significant at 1%

The sensitivity is commonly measured by the slope (β_j) of every firm's TFP to the index as follows. $\beta_j = \frac{\sigma_{jM}}{\sigma_M^2}$, where σ_{jM} the covariance of firm's TFP and the index, and σ_M^2 = the variance of TFP index. The slope is first computed for four quarters, then rolled over time with the first quarter being fixed up. In this case, the slope reflects the time-varying sensitivity of the firm's TFP. Usually, the slope has a benchmark of 1. The slope value that is greater than one shows firm-level TFP that changes faster than other firms in the index. The vice versa for the slope that is less than one. The negative slope shows a deterioration of firm-level TFP in comparison to other firms in the index. The results are reported in Table (4).

The results in Table (4) show that the estimates of Weighted Growth of Fixed Assets ΔWGFA are robust. That is, in the case of beta greater than one, a negative and significant association exists between firm growth and TFP. The same negative result is reported by Calvino, et al., (2018) and Shima (2010) using the technical efficiency in the Japanese firms. In case of beta less than one, the sign reverses to positive preserving its significance. This is an indication that the Weighted Growth of Fixed Assets ΔWGFA reflects the association with firm-level TFP. Indeed, the ΔWGFA reflects the dynamic efficiency of firm productivity (Fallah-Fini, et al., 2014).

5. Conclusion

This paper examines the impact and robustness of the association between four different measures of growth of the firm (namely, the weighted growth of fixed assets, growth rate of fixed assets, growth rate of sales, growth rate of total assets) and firm-level TFP. The empirical results show that there are significant, non-linear, and robust relationships between the weighted growth of fixed assets and firm-level TFP. This result extends the findings reported by Nilsen and Schiantarelli (2003). The results also show that the weighted growth of fixed assets has a significant positive effect on firm-level TFP. However, the other three measures of firm growth don't have significant effects on the firm-level TFP. Consequently, the findings in this paper show the importance for a firm to utilize fixed assets efficiently in order to eventually enhance its TFP.

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