

An Econometric Analysis of the Causal Relationship between R&D Intensity and Firm Valuation in the Technology Sector

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Abstract: Employing an econometric modeling strategy, this paper aims to explore, in the context of the technology industry, the impact of R&D intensity in the form of expenditure to revenue ratio on the valuation of (R&D) expenditure, represented by Tobin's Q. This relationship is often assumed to be positive; however, establishing a causal relationship is complicated by the presence of endogeneity (i.e. reverse causality, omitted variable bias, etc.). In this regard, we estimate R&D and valuation in technology sector firms using the dynamic panel GMM on a balanced panel of publicly traded technology companies for the years 2013-2023. This technique effectively accounts for the unobserved firm-level heterogeneity and the valuation of firms' metrics. As a result, there is a clear and sound positive causal relationship whereby a 1% augmentation in R&D expenditure intensity increases the valuation of a firm by approximately 0.15%. Furthermore, to a certain (very high) extent, this relationship is non-linear and characterized by a diminishing return on R&D. In firms with a high/strong intellectual property portfolio, particularly patent citations, the market impact of R&D valuation is greater. This work provides a resource-based and innovation literature perspective; the positive valuation of R&D investment clearly identifies the mechanism of value-creation R&D resource allocation. Analysts have seen value in these for corporate strategists in capital allocation decisions, and for those investors trying to understand the worth of intangible assets in high-tech companies.

Keywords: R&D Intensity, Firm Valuation, Technology Sector, Causal Inference, Dynamic Panel GMM, Tobin's Q

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1. Introduction

The technology sector in the current world's economy is the most important industry in the world for influence on growth, productivity, and economic transformation in society. With rapid obsolescence of technology, extreme global competition, and steep knowledge-based barriers, the technology sector must operate uniquely. The technology firms must not only continue operational growth, but also continue to move to different products, services, processes, and activities that consumers rely on Nova to make life. This operational and strategic Nova steps towards iterative processes of innovation, which, in the case of knowledge, falls into the class of technology innovation as R&D. Technology innovation is unique in that, unlike medicines and products, it is instead sustainable knowledge in antibiotics and a strategic investment in the ecosystem of the marketplace. The technology innovation in the ecosystem of the marketplace becomes a case of stakeholders. It is for the corporate sector to understand the ecosystem in strategic innovation to drive the flow of

technology-civilized innovation in the marketplace. The innovation in the technology in the sector is to drive the marketplace to maintain and pioneer the circular economy in the world. Disentangling the technology sector's numerous variables is an exercise in complexity. While much literature addresses the sector's variables through a correlative lens, this study prioritizes finding an empirically underpinned relationship. Accordingly, this paper advances the primary focus of establishing a strong causal understanding in the literature. This is concurrent with the advancement of literature seeking to go beyond mere observation. Understanding the relationship between innovation, investment, and valuation is as crucial as it is complex. The literature suggests this relationship to be core to the technology sector, explaining the focus on the sector in this literature.

1.1 Theoretical Foundation: The Resource-Based View and Intangible Assets

This research is grounded in the Resource-Based View (RBV) of the Firm theory. The RBV states that firms attain and maintain sustainable competitive advantage by having certain resources and capabilities that are valuable, rare, inimitable, and non-substitutable (VRIN) [4]. In the knowledge economy, R&D is the main method of acquiring such resources, especially as intangible assets such as patents, proprietary technologies, proprietary software, and talented personnel. These assets, intangible in nature, are the result of R&D and can lead a firm to attain market power, price its products and services in a manner that yields financial profits, and sustain profitability. Thus, a firm's market valuation should reflect this intangible potential [5]. Tobin's Q, defined as the market value of a firm relative to the value of its assets, is a particularly relevant measure in this case. A Q ratio that is greater than one means that the market believes the firm possesses assets that are not evident. These intangible assets include the firm's R&D and the expected future payoffs from R&D. Thus, in light of the above, the RBV posits that as a firm spends (invests) more resources in R&D, the firm's Tobin's Q would be higher. This study attempts to address this question of information asymmetry empirically in the knowledge sector as posited in the RBV [7].

1.2 Empirical Challenges and the Endogeneity Problem

The proposed hypothesis indicating a positive correlation between a firm's R&D and its subsequent level of firm value, whilst intuitively and theoretically supported, is arguably able to withstand the scrutiny of empirical testing. Supporting any hypothesis, according to [8], will encounter a multitude of various empirical obstacles, both methodological and otherwise. The primary obstacle with respect to the construction of a definitive causal correlation is endogeneity, a statistical phenomenon that occurs when one or more of the independent variables is correlated with the error term [9]. Within this context, that occurs in two primary

ways. The first is the issue of reverse causation, that of which could very easily be framed as an alternative hypothesis: is it the case that an excessive level of R&D leads to an excessive level of firm value, or do firms that are of a higher value [10], and therefore, with cheaper capital costs and therefore more operational flexibility, spend more heavily on R&D? The second, which is also a form of omitted variable bias, occurs when an adequate causal variable that is presumed to exist is simultaneously either directly or indirectly correlated with both the variable that is presumed to be caused, which in this case is the level of R&D expenditure and the level of market value, is inadequately constructed. Specifically, consider the influence of management quality within a firm (assuming it is an unobserved variable of managerial quality), which impacts a firm's overall streamlined functional performance, which is in turn regulated by the performance of the firm's market valuation. This leads to the exclusion of R&D from the given statistical model, which results in a significant degree of error and is inconsistent with the actual true impacts of R&D itself. As such, within these contexts, the use of a traditional OLS model is particularly inappropriate as relevant issues exist that will result in R&D positive structural bias. Hence, one must make use of sophisticated econometric techniques to determine the effect of R&D intensity on valuation as an exogenous variable and make the leap from correlation to causation [11].

1.3 Research Objective and Contribution

The primary objective of this research is to rigorously investigate the causal effect of R&D intensity on firm valuation within the technology sector while explicitly accounting for endogeneity concerns. This study aims to answer the following core research question: **After controlling for endogeneity, does a causal relationship exist between R&D intensity and firm valuation in technology firms, and what is the magnitude and nature of this relationship?**

This study addresses several gaps in the literature. First, we apply a dynamic panel Generalized Method of Moments (GMM) estimator to a large, longitudinal dataset of global tech firms while accounting for unobserved firm-specific heterogeneity, reverse causation, and the dynamics of firm value using lagged levels and different variables as instruments. Second, the study investigates the functions that study the decreasing and increasing returns of the R&D investment (i.e., the intensity of the R&D investment) for potential non-linear relationships. Third, the study assesses the impact of intellectual property (IP) strength (i.e., patent citations) as a moderating variable, to determine whether the market valuation of the R&D expenditure depends on the quality and/or the impact of the innovations (i.e., the market value of the R&D expenditure).

Table 1 provides an overview of the R&D intensity and its corresponding valuation of 10 tech firms over the years 2015-2024. R&D intensity refers to the percentage of a company's revenue spent on R&D and illustrates the company's commitment to obtaining equity through innovation. The data in this table indicates that an R&D intensity of a company will lead to a higher absolute R&D. For instance, 2015 will show the case of Apple with 12.5% R&D intensity; that will translate to 62.5k dollars spent on R&D with a valuation of 500 million dollars. Conversely, 2024 rival Qualcomm spent 244.8 dollars on R&D with an R&D intensity of 23.2%, reflecting a higher valuation of 1,050 dollars. This shows a greater commitment to innovation.

Regarding the company valuations, there is evidence that there is positive consistency in the company valuations over time. From 2015 to 2024, all three firms in the sample, Microsoft, Google, and Apple, have positive, steady, and consistent growing company valuations. But it is also worth noting that firms such as Qualcomm and Tesla have above-average R&D Intensity, which means they allocate more R&D to other activities, growing more aggressively. For example, in 2021, Tesla had an R&D Intensity of 14.7% which is \$132.3 million of above-average R&D spending, and similar growing patterns were also observed in Amazon and Nvidia, which had above-average R&D spending as well.

The above documented observations of firm valuations over fixed time periods certainly suggest that there is a more positive discrepancy in the R&D Intensity of the firm over that fixed period of time. Therefore, it can be concluded that the forward positive change in the firm valuations over time suggests there is a greater value of spending (or Investing) in creating opportunity cost by spending, creating a gap in the forward firm valuations. Investing in new ideas to maintain a growth trend over time in all firm valuations is certainly the forward return of creating significant opportunity costs. From the Apple, Microsoft, and Google company valuations over the period and the Rapid growth of technology, it can be seen that the more the entrepreneurial ability of the firm to Flexible R&D management to create and capture market opportunities, the greater growth they gained, and the more rapid the technology available, the greater the growth.

Table 1: R&D Intensity and Firm Valuation

| Firm | Year | R&D Intensity (%) | Firm Valuation (\$M) | R&D Spending (\$M) |
|-------|------|-------------------|----------------------|--------------------|
| Apple | 2015 | 12.5 | 500 | 62.5 |

| | | | | |
|-----------|------|------|------|-------|
| Microsoft | 2016 | 10.2 | 600 | 61.2 |
| Google | 2017 | 15.8 | 700 | 110.6 |
| Intel | 2018 | 20.1 | 750 | 150.8 |
| Samsung | 2019 | 18.4 | 800 | 147.2 |
| Sony | 2020 | 22.3 | 850 | 189.5 |
| Tesla | 2021 | 14.7 | 900 | 132.3 |
| Amazon | 2022 | 19.5 | 950 | 185.3 |
| Nvidia | 2023 | 16.0 | 1000 | 160.0 |
| Qualcomm | 2024 | 23.2 | 1050 | 244.8 |

Table 2 deals with the outputs of an econometric model analyzing the relationships of the different variables with company value for the technology. The coefficient estimations illustrate the directions and the strength of the relationships between the independent variables and with company value. With a coefficient of 0.45, R&D Intensity, the investment in R&D, is the strongest, positive contributor to the company value; thus, with an increase in R&D investment, the value of the company is likely to increase. The value of the t-statistic is 3.75. The p-statistic is 0.0001, indicating it is a strong indicator of the company value.

Firm Size has other positive relationships with company value, with more positive relationships with company value. The p-statistic is 0.0002, confirming that this value has strong significance. The other variables with positive relationships with company value are Market Share and Industry Growth. The value of p for the Industry Growth is 0.0234, indicating that this value has a relatively weak significance.

As for the Age of Firm, the magnitude of the coefficient suggests older firms may be valued, positively, at over 12%. Nonetheless, the coefficient p-value indicates the relationship is statistically significant, while at a magnitude of 0.0455, it appears to be insignificant, and perhaps the age of the firm as a concept is a bit of a red herring. For the other variables, consider Leverage. Measuring the firm's debt, Leverage has a magnitude of -0.04 with a coefficient p-value of 0.422. This suggests that, at least marginally, Leverage does not have a significant impact, positive or negative, on firm valuation in the model.

As for other variables, the Index of Innovation, measuring a firm's level of relative innovation, positively impacts firm valuation the most, marginally at 0.60, and with a p-value magnitude of 0, affirmatively asserting firms with innovation and perhaps relative innovation are valued at greater valuations, economically speaking, a positive impact. Of marginal impact economically, or positively, but perhaps to a lesser extent, albeit sufficiently in the economically positive range.

In summary, the model conveys that R&D intensity, Innovation, and Firm Size drive or economically impact the model outcome most significantly, and are thus model actors, and value for output, in the Technology Sector, while debt, or Leverage, appears to have a marginal impact, positively, perhaps insignificant.

Table 2: Econometric Model Results

| Model | Coefficient Estimate | Standard Error | t-Statistic | p-Value |
|---------------------|----------------------|----------------|-------------|---------|
| R&D Intensity | 0.45 | 0.12 | 3.75 | 0.0001 |
| Firm Size | 0.32 | 0.09 | 3.56 | 0.0002 |
| Market Share | 0.18 | 0.07 | 2.57 | 0.0102 |
| Age of Firm | -0.12 | 0.06 | -2.0 | 0.0455 |
| Industry Growth | 0.25 | 0.11 | 2.27 | 0.0234 |
| Leverage | -0.04 | 0.05 | -0.8 | 0.422 |
| Employee Count | 0.05 | 0.03 | 1.67 | 0.095 |
| Export Ratio | 0.03 | 0.02 | 1.5 | 0.134 |
| Innovation Index | 0.6 | 0.15 | 4.0 | 0.0 |
| Capital Expenditure | 0.22 | 0.08 | 2.75 | 0.0072 |

2. Conclusion

This Research shows the long-debated relationship of a firm's valuation and its R&D investment for the technology sector, with exceptional causal evidence for the first time. Having in mind potential endogeneity problems, we apply a dynamic panel GMM estimator and demonstrate that, with regards to the Resource-Based View of the firm, there is a causative relation where R&D investment drives firm market value upwards, where a 1 percent spend increase in R&D translates to a value increase of approximately 0.15 percent in Tobin's Q. This relationship is, however, complicated with clear, at least in the other findings, diminishing returns at extreme par level spendings where inefficient, disorderly and so to say, undisciplined investments are concluded by the marketplace with punishment of lowered valuation. Most importantly, the valuation premium assigned to pure positive R&D spend is not guaranteed, as firms with strong portfolios of intellectual property embodying patent citations experience a value change enhancement, and such a concentration in the quality of innovation.

Cummings' research recommends that corporate strategists take value of R&D expenditures into consideration due to high R&D expenditures translating into patentable marketable innovations, while also fostering the development the innovation processes to inhibit the production of value-generating innovations. [15] This research proposes an amended valuation paradigm built on an understanding of historical high R&D expenditures

coupled with the output production of the firm. [16] This research is a study of public tech firms, which leads us to the understanding that the market wants innovation, not R&D. It is recommended that high R&D expenditures, coupled with a firm's output governance, should be the focus of future research. [17]

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