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New-Product Research and Development: The Earliest Stage of the Capital Structure

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ABSTRACT: New product R&D, which precedes post-launch production, is a three-stage process. First comes idea prospecting, which leads to working prototypes. Second comes productization—the conversion of working prototypes into manufacturable products with reasonable prospects of being profitable. Thirdly, firms produce pre-launch inventories. This process often involves high risk, not only due to the large amounts of time and capital investment, but also because the secrecy maintained across lateral competitors stifles market signals that ordinarily foster economic efficiency. Reconsideration of the Austrian theory of the business cycle in this light leads to additional insights about: 1) the capital consumption that occurs during the cycle; and 2) the timing of the bust that follows a boom inspired by excessive credit expansion. Our empirical study of return volatility for the period from 1996 to 2017: 1) confirms the results of a *Journal of Finance* study of the preceding period from 1975–1995; and 2) validates our analysis of new-product R&D as the earliest component of the capital structure.

KEYWORDS: research and development, R&D, business cycle, capital structure, capital consumption

JEL CLASSIFICATION: E14, E32, O30

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> Our friends up north [at Microsoft] spend over five billion dollars on research and development and all they seem to do is copy Google and Apple. - Steve Jobs

I. INTRODUCTION

Austrian economics emphasizes the idea that the price and production signals of competing firms coordinate capital use across the stages of production. This idea makes perfect sense for firms whose priced products are competing on the open market. For example, the price and production decisions of competing automobile manufacturers influence one another. On the other hand, the decisions of firms engaged in *new-product* research and development are largely uninformed by the decisions of other firms engaged in the research and development of similar products. Because, by definition, new-product R&D occurs *prior* to the pricing and open market sale of products, competing firms within this stage of the capital structure are largely ignorant of each other's preparations.

In this paper, we deepen the understanding of the capital structure by unpacking the *process* that coordinates capital within the new-product R&D stage of the capital structure. The dearth of capital-coordinating signals emanating *from* the earliest stage of the capital structure is unique to the new-product R&D process. Signals, within the new-product R&D stage, are sparse for three reasons: 1) price and production signals do not exist for products still under development or prior to launch on the open market; 2) pre-launch inventories have minimal impact upon the market price of products already on the market; and 3) entrepreneurs, engaged in new-product R&D and seeking "first mover" advantage, have incentives to shroud their operations and discoveries in secrecy.

The evidence of entrepreneurial secrecy in new-product R&D can be found in the body of law dealing with trade secrets. Firms, engaged in new-product R&D, routinely require employees to sign: 1) "non-disclosure agreements" whereby employees obligate themselves to keep research and development activities secret; and 2) "invention agreements" that pre-specify the sharing arrangement for anything that employees invent during or as a

result of their work on the firm's new-products.[1] Together, the overt secrecy of entrepreneurs regarding new-product R&D and the absence of price and production signals reduce and/or delay the cost-dampening impact of inter-firm competition.

We organize the remainder of this paper as follows. In Section II, we present time lines that facilitate the understanding of: a) the roles that time and money play in sustainable new-product R&D processes; and b) the system-wide costs of entrepreneurial secrecy and the absence of competition-constraining price and production signals. In Section III, we explain how our more explicit discussion of new-product R&D: a) deepens understanding of "capital consumption" in Austrian business cycle theory; and b) offers new insights into the trigger and timing of credit expansion booms and busts. Section IV presents an empirical study that validates our emphasis upon new-product R&D as the earliest component of the capital structure—our study demonstrates for the period 1996 to 2017 the same positive association between share price volatility and R&D intensity found in a *Journal of Finance* study pertaining to the preceding period, from 1975 to 1995. A summary follows in Section IV.

II. SUSTAINABLE NEW-PRODUCT R&D

The process of new-product research and development consists, by definition, of new product research followed by new product development. We define *new product research* as prospecting for new and viable innovations (the search for working prototypes). *New product development* is *pre-launch production* consisting of: (a) the productization of cost-efficient working prototypes; and (b) the

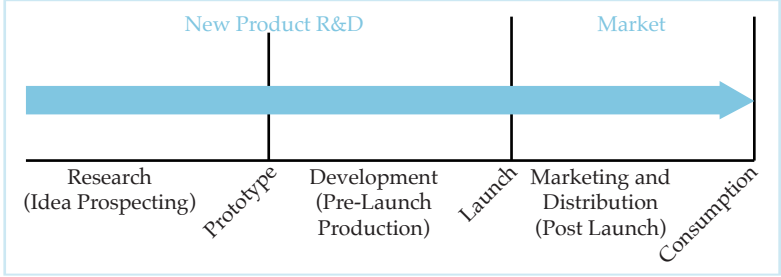
[1] "...[T]he term 'trade secret' means all forms and types of financial, business, scientific, technical, economic, or engineering information, including patterns, plans, compilations, program devices, formulas, designs, prototypes, methods, techniques, processes, procedures, programs, or codes, whether tangible or intangible, and whether or how stored, compiled, or memorialized physically, electronically, graphically, photographically, or in writing if—(A) the owner thereof has taken reasonable measures to keep such information secret; and (B) the information derives independent economic value, actual or potential, from not being generally known to, and not being readily ascertainable through proper means by, another person who can obtain economic value from the disclosure or use of the information…." 18 U.S. Code § 1839. Definitions accessed online at: https://www.law.cornell.edu/uscode/text/18/1839.

production of enough initial inventories to meet the anticipated demand for products launched onto the open market.

The timeline shown in Figure 1 illustrates the process by which new-product R&D *successfully* delivers new products to consumers. Successful processes begin with idea-prospecting that leads to working prototypes. Next, working prototypes evolve into products with costs that end up, after product launch, to be sufficiently low for the products to generate at least normal expected returns. Finally, firms produce sufficient quantities of pre-launch inventories to meet expected demand and be competitive on the open market. The arrow in Figure 1 shows the *successful* start-to-finish new-product R&D process: from idea prospecting, to prototype, to productized pre-launch inventory, to marketing and distribution of the completed products on the open market, and finally into the hands of consumers.

Not all investments into *new-product* R&D will be successful; in fact, many are likely to fail. This is because across the new-product R&D stage shown in the Figure 1 timeline, there is, as mentioned in the introduction, a dearth of market signals. Again: 1) neither price nor production signals can exist for products in *pre*-production; 2) pre-launch inventories have minimal impact on the market price of products already on the market; and 3) in the pursuit of "first mover" advantage, firms engaged in *new-product* R&D routinely stifle signals about their operations.

Figure 1: Timeline of How New Products Reach Consumers



The *dearth* of market signals *within* the new-product R&D stage *does not* mean that *no* market signals inform capital use within this stage. Most importantly, as emphasized by renowned Austrian school

thinkers (Mises, Hayek, Garrison, etc.), the interest rate at which firms borrow has its most significant impact upon the capital structure's earliest components. Also price, production, and other signals from active markets, *outside* the new-product R&D stage, provide crucial guidance that usefully informs, directs, and constrains new-product R&D. Summarizing, the three market signals that most clearly inform capital usage in new-product R&D are: (1) the interest rate on loanable funds; (2) the price and production signals of related products (substitutes and complements) currently being exchanged on the open (post-launch) market; and (3) the prices of the inputs available on the open market.

In line with standard Austrian business cycle theory (ABCT), so long as these market signals from *outside* the new-product R&D stage are free from artificial constraints or subsidies, we anticipate that entrepreneurial error in new-product R&D will be constrained *sufficiently* to preclude malinvestment booms. But given the absence of lateral signals *within* the new-product R&D stage, again consistent with standard ABCT, there is every reason to suppose that an excessive expansion of credit will drive the interest rate below the natural rate, and swell entrepreneurial errors in new-product R&D, leading to an unsustainable malinvestment boom. Before discussing such an unsustainable boom, we begin below by first discussing sustainable levels of the entrepreneurial errors that occur—when investment is constrained by free market prices and the natural rate of interest. In particular we discuss three types of errors: (1) superfluous discovery; (2) duplicative discovery; and (3) duplicative development. We discuss each of these in turn.

Superfluous Discovery

Superfluous discovery occurs within the idea prospecting (research) phase of new-product R&D. Superfluous discovery occurs when prototypes, or models: 1) do not work; or 2) are economic dead-ends (because the costs of productizing and launching exceed the prototypes' expected future returns. For example, in the academe, all those who have conducted significant amounts of research have made arguments that simply do not "work out." There are a variety of reasons for unpublished academic research; among them: 1) the implications of the model

are grossly inconsistent with observable, real-world behavior; and 2) the argument is unclear and/or unpersuasive to peer reviewers.

Duplicative Discovery

Duplicative discovery occurs when more than one entrepreneur, engaged in research, discovers the same working prototype, or model, simultaneously (or nearly simultaneously). Matt Ridley (2017) explains that many versions of the light bulb existed before Thomas Edison "invented" it:

> Suppose Thomas Edison had died of an electric shock before thinking up the light bulb. Would history have been radically different? Of course not. No fewer than 23 people deserve the credit for inventing some version of the incandescent bulb before Edison, according to a history of the invention written by Robert Friedel, Paul Israel and Bernard Finn.

Ridley goes on to cite a famous example in the history of science—Darwin's and Wallace's simultaneous discovery of the theory of evolution.[2]

Duplicative Development

Duplicative development occurs when, following the awareness of increased demand for a product, a "swarm" of firms, not all of which will ultimately survive, make investments to bring similar products to market. For example, in early January of 2007, Apple Computer announced and demonstrated the *iPhone*. Shipment of the new device began in June of that year with great fanfare and

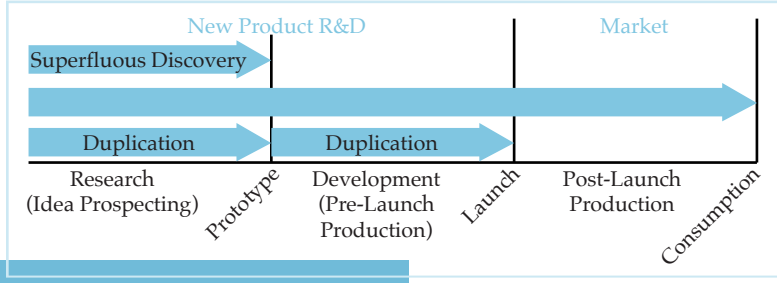
[2] "Charles Darwin was a methodical man. Twenty-two years after the voyage of the Beagle, he was still working on his definitive study. Darwin, in fact, almost waited too long. In 1858, Alfred Russel Wallace also formulated a theory of evolution, based on his studies in Brazil and the East Indies. … [W]hen Wallace sent the manuscript of his findings to Darwin for his opinion, Darwin was astounded. Although Darwin's first instinct was to give Wallace full credit for the theory, the two men agreed to present their papers in the same issue of the *Journal of the Linnean Society*. The next year, 1859, Darwin finally finished his book, *On the Origin of the Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*; the popular title is *The Origin of the Species*." (Ritchie and Carola, 1983, p. 509)

significant market adoption. The success of the new smartphone served as an impetus for other firms to engage in developing competitive products. One after another, Palm, Blackberry, Microsoft, Samsung, Nokia, and the browser company Mozilla (creator of Firefox) among others, invested heavily in the development, prelaunch inventories, and launch of their smartphone offerings. The result of this entrepreneurial swarming into the smartphone space was a successful Samsung/Google Android phone and the original leader, iPhone from Apple. The others, unable to compete successfully in the crowded space, dropped out of the race or fell into obscurity.

The three entrepreneurial errors (again, superfluous discovery, duplicative discovery, and duplicative development) can reduce the overall *ex post* net benefit of the new-product R&D stage of the structure of capital. However, there is no reason to think that the market signals from outside this stage (i.e., prices of related goods, the prices of inputs, and the interest rate) will, absent distortions in these outside signals, so insufficiently constrain these errors as to cause the *ex post* net benefit of new-product R&D to be negative. Schumpeter's oxymoron, "creative destruction," is famous because new-product R&D has repeatedly delivered net benefits that are palpably positive.

This in mind, we argue that the new-product R&D process, absent governmental and/or credit distortions, will be *sustainable*—meaning that the *ex post* net benefits are positive. In Figure 2, we modify Figure 1 (which only addressed sustainable new-product R&D), to include the entrepreneurial errors of superfluous discovery, duplicative discovery, and duplicative development.

Figure 2: Sustainable New-Product R&D Timeline



As depicted in Figure 2, entrepreneurial errors appear in lengths and widths intended to depict *sustainable* levels, (that is, levels that result in the overall net benefit of new-product R&D being non-negative). As shown in Figure 2, the superfluous discovery arrow ends at the prototype line—this is the *sustainable* level, meaning that resources are *not* invested into productizing uneconomic prototypes or non-working innovations.

Similarly, the "duplication" arrow in research (this arrow represents the duplicative research) ends at the "Prototype" line. Once there is proof of the viability of a prototype, concept, or model, no more resources go to re-discovering it. In the case of the light bulb, as Ridley explained in his APEE presentation (2017), it resurfaced many times only because worldwide communications at the time limited the knowledge of the various inventors. Subsequently, once knowledge of the invention of the light bulb became widely known, reinvention of the basic bulb ceased.

Finally, Figure 2 features a "Duplication" arrow above "Development." This arrow illustrates the level of duplicative initial inventory creation that is consistent with a sustainable new-product R&D process. Notice that this arrow ends at the *launch line*. This is not because duplicative products *never* reach final consumers, but because they *soon* cease to reach consumers—crowded out by the relatively more successful new product(s).

Returning to the cell phone example mentioned above, although many companies offered alternatives, today, only a few types remain on the market. In the period of a few decades, market competition winnowed the field. We do not know of any economist who argues that the costs of this winnowing process (the costs of duplicative development) are so large as to cast significant doubt about whether the research and development process that created cell phones delivered positive net benefits. In other words, the process that created cell phones was a sustainable one.

III. R&D MALINVESTMENT: ANOTHER SOURCE OF *CAPITAL CONSUMPTION*

The original Mises/Rothbard/Hayek renditions of Austrian Business Cycle Theory (ABCT), as Salerno (2012, p. 15) explains,

all agreed that 1) "malinvestment," excessive investment in the earliest stages of the capital structure, is an essential component of the boom; and 2) "overconsumption" is an essential component of the boom, albeit with Hayek being "less emphatic." In addition, "capital consumption" resulting from overconsumption during the boom, Salerno (p. 21) explains, is what ultimately leads entrepreneurs to abandon the "wholly new investment projects" undertaken during the boom.[3]

Our focus and more explicit discussion of new-product R&D, as the earliest component of the capital structure, provides a complementary explanation for the "capital consumption" that takes place during the boom (setting up an inevitable bust). Salerno's emphasis that it is "wholly new investment projects", in the earliest stages of production, that will be incentivized by the credit expansion (many of which will have to be abandoned due to "capital consumption"), dovetails with our focus on new-product R&D as the *earliest* component of the capital structure.

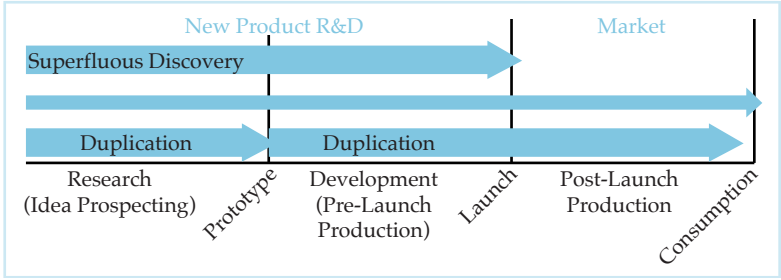
The additional source of capital consumption, that our unpacking of new-product R&D exposes, is straightforward. An artificially low interest rate, caused by the overexpansion of credit, will result in the bloating of Figure 2's *sustainable* levels of superfluous discovery, duplicative discovery, and duplicative development (levels that were sustainable at the natural rate of interest) into *unsustainable* levels (levels incentivized by the artificially low interest rates). For complete clarity, Figure 2's depiction of the *sustainable* R&D timeline is modified in Figure 3's depiction of an *unsustainable* R&D time line.

Comparing Figures 2 & 3, the bloating of superfluous discovery, duplicative research, and duplicative pre-launch production is obvious. As documented and emphasized by Salerno (p. 5), "Austrian theory is *not* an 'overinvestment theory' of the business cycle and was never construed as such by its most notable proponents." In line with Austrian theory and tradition, this means

[3] "[T]he increase in the prices and profitability of consumer goods diverts factors from higher stages to consumer goods' industries, thereby restricting the supply of resources available to add to or even replace the stock of capital goods. This is what Austrian economists call "capital consumption," which is a pervasive feature of the boom." (Salerno, p. 16)

that the bloating of the arrows in Figure 3, relative to Figure 2, is *not* overinvestment, but rather *malinvestment*.

Figure 3: Unsustainable R&D (bloated Superfluous Discovery and Duplication)



In one crucial respect, malinvestments specific to the new-product R&D stage are like malinvestments in early stages of the capital structure generally. All malinvestments arising from credit expansion contribute to what Salerno (p. 22) aptly describes as the "... 'hole' in the middle stages of the structure of production, which is 'papered' over by profits and capital gains caused by the falsification of monetary calculation." In one important respect, however, malinvestments in new-product R&D are unique. As we explained earlier, lateral competitors engaged in new-product R&D, with their products not on the market, are in the dark because they are literally uninformed by the price and production signals of one another.[4]

The uniqueness of new-product R&D malinvestment is important because it offers new insights into: 1) why new-product R&D malinvestments will tend to pile up for a longer period than will malinvestments where price and production signals are present; and 2) what can trigger the bust, and when it will occur. Current Austrian explanations of what will trigger the bust, and when, are unspecific. Garrison (2001, p. 72), for example, explains only that "at some point in the process. . . entrepreneurs encounter

[4] Recall from our earlier discussion that: 1) products under development are not yet on the market; and 2) in the pursuit of "first mover" advantage entrepreneurs in new-product R&D maintain secrecy about their activities.

resource scarcities that are more constraining than was implied by the patter of wages, prices, and interest rates that characterized the early phase of the boom. Here, changing expectations are clearly endogenous to the process."[5]

Inspection of Figure 3 suggests an explanation of what can trigger the bust, and when. Recalling from our previous discussions that the capital usages within the new-product R&D stage are non-signal emitting, it becomes apparent that the "launch" line is key to understanding what triggers the bust. Again, prior to launch, there are no price and production signals to constrain lateral competitors. It is at the time of product launch, that price and production signals for newly developed products first emerge and begin to constrain and coordinate capital usage across the stages of production. All that need occur to trigger a crisis is for an excessive amount of duplicative pre-launch inventory to hit the market simultaneously, or nearly so, in a Schumpeterian swarm.[6] This insight can improve our understanding of the timing of monetary inspired crises as illustrated by the two cases examined in the next section.

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[5] Similarly, Salerno (p. 22) explains:

> As the boom continues, firms confront an increasing scarcity of the resources necessary to [for example] fully utilize the new mining and oil drilling equipment to construct the hydroelectric plant and to engineer and mass produce the new generation of aircraft. In a strictly metaphorical sense, then, we may say that the lengthened structure of production cannot be 'completed.' The anticipated demands for the products of the higher stage investment projects... do not materialize because of the greater scarcity and costliness of the complementary labor and capital needed to profitably transform these products into lower order capital goods.... From an economic point of view, malinvestment and capital consumption cause the structure of production to disintegrate into pieces that cannot be fitted back together again without a protracted recession-adjustment process.

[6] An anonymous referee indicated that he/she, in discussing R&D as the earliest stage, emphasizes "the bringing to market of new capacity as a critical trigger (rather than pre-launch inventories)." Both are important, because both new capacity and the pre-launch inventories hitting the market can, if of sufficiently large magnitude, cause the price of competing products to collapse—and the price collapse is the defining characteristic of the bust. Empirical assessment of the relative importance of the new capacity relative to the launch of new inventories is beyond the scope of this paper.

IV. EVIDENCE OF GREATER VOLATILITY IN R&D-INTENSIVE FIRMS

According to Austrian business cycle theory, excessive credit expansions drive the interest rate below the natural rate and, thereby, incentivize overinvestment in the earliest components of the capital structure. In line with this theory, it is expected that the uses of capital in the earliest stages would be more volatile over the business cycle as the interest rate deviates from the natural rate. In this paper, we have focused attention upon new-product R&D (pre-production investment) because it is the earliest component of the capital structure and because the activities of businesses in the new-product R&D space are *sequestered*—the price and production signals that ordinarily constrain and coordinate the stages of post-product-launch production literally do not exist to coordinate and constrain pre-production enterprises. If this focus is apt, then, empirically, we should expect to see greater volatility in the values of firms that are more heavily engaged in new-product R&D.

A. Extant Empirics on R&D Intensity and Return Volatility, 1975–1995

A relatively recent study in the *Journal of Finance* provides evidence on the impact of new-product R&D on return volatility over the period 1975 to 1995. Chan, Lakonishok and Sougiannis (2001, p. 2431) find that "R&D intensity is positively associated with return volatility." Their explanation? Consistent with our discussion of new-product R&D as *sequestered capital*, they point out that research and development activity is, under "accepted U.S. accounting principles," treated as an "intangible asset" and that this results in a general "lack of accounting information" which greatly "complicates the task of equity evaluation" (*op cit*.) for firms that are highly R&D intensive.[7] To verify that these findings extend beyond the period from 1975 to 1995, the remainder of this

[7] Furthermore, studying the impact of this lack of information upon stock market valuations is important, they argue, because of the recent, "dazzling growth" in R&D intensive industries—"at year-end 1999, the technology sector and the pharmaceuticals industry together account for roughly 40 percent of the value of the S&P 500 index." (*op cit*., pp. 2431–2432).

section empirically investigates the relationship between R&D intensity and return volatility for the period from 1996 to 2017.

B. A Study of R&D Intensity and Return Volatility for 1996–2017

The purpose of this empirical study is to test the hypothesis that the sequestered nature of new-product R&D implies that firm share-price return volatility increases as R&D intensity rises. Our study presents a series of four OLS panel-data regressions that estimate, for alternative specifications, the statistical and economic significance that new product R&D has on firm volatility. The regressions estimate the coefficient of three-year trends in the new product R&D (*RD_Trend*) of 3,668 publicly traded firms as a predictor of the dependent variables, *Market_Beta* and *Total_Volatility*.

Investors regularly rely on *Market_Beta* as a measure of potential risk, reflecting the volatility of a firm's stock price compared with that of the market as a whole. A beta of 1 indicates that the firm's volatility mimics the volatility of the market, while a beta greater than 1 reports the percentage increase in volatility of a stock above the volatility of the market. A beta less than 1 indicates a percentage decrease in volatility in comparison to that of the market.

To control for potential omitted variable bias, we have included the natural log of each firm's annual total revenues as well as annual net income as a percentage of total revenues. All regressions include both year and firm fixed effects, to control for aggregate movements in the market (business cycles) and for attributes of firms and industries.

The data we use are from *WRDS-Compustat*. Table 1 presents descriptive statistics on the variables used in the regressions. As shown in the table there are 32,121 observations of which, for each firm, there are up to 21 annual observations (1996 to 2017.) The years 1993 to 2017 are included in the data. The years 1993 to 1995 are included to calculate the three-year averages of total revenues and total R&D expenses used in the regressions. The market beta values range from 0 to 16.42, representing a broad range of volatility compared to the market volatility of 1.

Table 1: Summary Statistics

Variables	Labels	N	Mean	StdDev	Min	Max
Year	Year of Observation	32,121	2006		1993	2017
Beta_Market	Beta Against Market	32,121	1.281	0.876	0	16.42
Tot_Volatility	Total Firm Volatility	32,121	0.147	0.0935	0	2.445
Net_Income	Income as % of Revenue	32,121	–0.0153	0.325	–2.999	0.996
LN_Total_Revenue	Nature Log of Revenue	32,121	5.872	2.176	0.00399	13.12
RD_Intensity	Three Year Trend in RD	32,121	0.0759	0.107	0	0.969

Total Volatility represents the range of volatility on a firm basis over a three-year period. The Net Income values represent the actual net income divided by Total Revenues or a percentage of Total Revenues. The natural log of Total Revenues is calculated by taking the natural log of the Total Revenues in millions. The *RD_Intensity* variable is computed by taking the total R&D expense for the current year and the two prior years and dividing the total by the total of revenues over the same three years.

1. Estimation Methods

To assess the relationship between share-price volatility and R&D intensity, we estimate the model

$$(1)\ y_{it} = \beta \text{RDIntensity}_{it} + \alpha X_{it} + \mu_i + \nu_t + \varepsilon_{it},$$

where y_{it}, depending on the specification, is either the *Market Beta* (a standard measure of performance volatility) or *Total Volatility* of each firm (i) in year (t). The vector $RDIntensity_{it}$ includes the average of the new product R&D as a percentage of total revenues for current year (t) and the previous two years. In estimations in which *Market_Beta* is the dependent variable, the coefficient estimates on $RDIntensity_{it}$ measures the percentage impact of an increase in R&D as a percent of total revenues on *Market Beta*—a 1 percent increase in $RDIntensity_{it}$, the estimated coefficient is the

predicted increase in *Market Beta*. When the dependent variable is *Total_Volatility*, a 1 percent increase in $RDIntensity_{it}$ results in an increase in the total volatility of the firm's value by the percentage reflected by the coefficient.

All regressions include firm and year fixed effects, μ_i and ν_t respectively. Year fixed effects capture price movements in the market that are largely systemic and often representing business cycle impact. Firm fixed effects capture time-invariant firm observable and unobservable variables, such as product market focus. The identifying assumption in our model is that firm trends are parallel.

The X_{it} vector in the regression model includes firm financial variables such as the log of total revenues and net income as a percent of total revenues, aggregated to the firm and year level. We include these variables to control for the possibility that changes in firm size and profitability might affect volatility.

2. Results

The estimation results of our empirical study are shown in Table 2. The table includes two sets of regressions run against *Market Beta* (regressions 1 and 2) and two run against *Total Volatility* (regressions 3 and 4.) In the first regression, column (1) of Table 2, the control variables for *Total Revenue* and *Net Income* are omitted to provide a comparison for evaluating their impact when included as shown in regression (2). The coefficient of *RD_Intensity* is 0.928 and is significant at the one percent level, suggesting that an increase of one percentage of total revenues expensed on R&D will result in an increase in the firm's market beta of 0.928 or approximately 92.8 percent—an economically significant increase.

In the second regression, column (2) of Table 2, the control variables for *Net Income* and *Total Revenue* are added into the model. The coefficient on *RD_Impact* declines from the first regression to 0.629, remaining significant at the one percent level and suggesting that an increase of 1 percent in the percentage of total revenues expensed on R&D will increase the firm's market beta by 62.9 percent. The control variables suggest, as expected, that firms with higher revenues and profits will have lower beta values and thus lower volatility.

Table 2: Empirical Findings, 1996–2017; Effect of Research and Development Intensity on Stock Volatility

Variables	(1) Market Beta	(2) Market Beta	(3) Total Vol	(4) Total Vol
RD_Intensity	0.928***	0.629***	0.136***	0.0469***
	(0.0967)	(0.0995)	(0.0117)	(0.0108)
LN_Total_Revenue		–0.0139***		–0.0144***
		(0.00515)		(0.000644)
Net_Income		–0.204***		–0.0326***
		(0.0312)		(0.00316)
Observations	32,121	32,121	32,121	32,121
Number of Firms	3,654	3,654	3,654	3,654
Year Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes

Notes: Statistical significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***. The dependent variable for (1) and (2) is market beta (a standard measure of stock volatility) and for (3) and (4) total volatility, which is the volatility of each firm considered independently. All regressions include firm and year fixed effects and report robust errors.

In the third regression, column (3) of Table 1, the control variables for *Total Revenue* and *Net Income* are omitted to provide a comparison for evaluating their impact when included as shown in regression (4). The coefficient of *RD_Impact* is 0.136 and is significant at the one percent level, suggesting that an increase in the percentage of total revenues expensed on R&D will result in an increase in the firm's total volatility by approximately 13.6 percent—an economically significant increase.

In the fourth and final regression, column (4) of Table 1, the control variables for net income and total revenue are included in the model. The coefficient on *RD_Impact* declines from the first regression to 0.0469, remaining significant at the one percent level and suggesting that an increase of 1 percent in the percentage of total revenues expensed on R&D will increase the firm's market beta by 4.69 percent. As in regression (3), the control variables suggest a lower level of total volatility when a firm has higher revenues or net profits.

3. Summary of our empirical findings for the period 1996–2017

The empirical results of the four panel-studies reported in Table 2 strongly suggest a causal correlation between increases in the percentage of revenues expended on new product R&D and significantly higher levels of price volatility. This finding is consistent with our hypothesis that the sequestered nature of new product R&D will lead to greater error on the part of investors in forecasting—resulting in greater volatility.

V. OVERALL SUMMARY

According to Austrian business cycle theory, excessive expansions of monetary credit cause malinvestment in the earliest component of the capital structure. In this paper we have analyzed the implications of *new-product R&D* in its role as the earliest uses of capital. As we have explained, new-product R&D can be broken down into three sequentially occurring stages: 1) a research stage that discovers potential new products; 2) a development stage to turn the potential products into working prototypes and productize them; and 3) a final stage to develop (produce) *pre-launch* inventories. Throughout these three stages, capital is *sequestered*—for these pre-production stages laterally competing firms are in the dark about the prices and production that will, following product launches, emerge onto the open market. Consistent with this sequestration of capital in the earliest stages, we find that, consistent with a previous empirical study for the period 1975 to 1995, higher return volatility is associated with higher R&D intensity. By identifying three stages of new-product R&D as the earliest component of the capital structure, greater insight is possible into what will trigger malinvestment busts and when they are likely to occur.

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