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Production Efficiency as a Priced Factor: Industry Evidence from the United States

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Abstract. This paper tests the von Neumann-Gale (VNG) production-based asset pricing model, which predicts that production efficiency should be a priced factor in stock returns. Using total factor productivity (TFP) growth as a proxy for efficiency, this paper examines four U.S. industries (Retail, Wholesale, Manufacturing, and Transport) from 1990 to 2018, a period covering two business cycles and the 2008 financial crisis. Full sample results indicate that only the Retail industry shows a significant positive relationship between TFP growth and positive excess return (referred as VNG prediction). However, the 2008 financial crisis changes this particular relationship: Retail no longer continues to positively contribute whereas Wholesale post-crisis demonstrates a significant negative TFP-return relationship (i.e. a low productivity premium). Manufacturing and Transport exhibit no significant relationship in all evaluated years. The results of this paper claim have VNG model industry-level evidence, document crisis-induced pricing of productivity to reverse sign and define the importance of sector-specific investments during financial crisis.

Keywords: Production Efficiency, Priced Factor, United States

1. Introduction

The central issue in asset pricing is why some stocks could earn a higher return than others. The classic Capital Asset Pricing Model (CAPM) which was proposed by Sharpe & Lintner, answers that beta measures systematic risk [1]. However, decades of empirical anomalies have also shown that many other characteristics--such as size, value, momentum, and profitability--also explain the cross-section of stock returns. In response, multifactor models, most notably the Fama-French three-factor model, have incorporated these characteristics as risk factors [2].

Yet one important characteristic has received relatively less attention in mainstream multifactor models: production efficiency. Intuitively, firms that transform inputs into outputs more efficiently should be more profitable and thus command higher stock returns. But is this intuition robustly priced in the market? And does it hold across different industries and over time? This study tests this using the von Neumann-Gale (VNG) convex production technology [3, 4].

In empirical research, the author will use Total Factor Productivity (TFP) growth as a measurable proxy for \u03b3, which is reasonable as TFP accounts for the residual output that is not attributed to capital and labor and is recognized as the most standard measure of production efficiency in the economic literature. The author will focus on four sectors of the economy in the United States

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(Retail, Wholesale, Manufacturing, and Transport) over the period of 1990 to 2018. This period has been inclusive of two business cycles as well as the 2008 financial crisis.

The findings are important in that it supports the VNG model at the industry level, it describes the phenomenon of crisis-induced sign reversal, and it provides direction to sector-certain investment strategies [3, 4].

The paper is structured as such. Section 2 presents the VNG framework. Section 3 presents the data. Section 4 presents empirical findings. Section 5 is the discussion, and Section 6 is the conclusion.

2. Theoretical framework

This chapter is an assessment of the literature on three themes - production based asset pricing, empirical consideration of TFP and stock return correlation, and financial crisis and productivity pricing - and aims to derive testable propositions.

2.1. Production-based asset pricing and the role of efficiency

The VNG framework for convex production technology provides a theoretical basis for the nexus of production efficiency and asset returns [3, 4]. Within this framework, the efficiency parameter γ (the maximum output-to-input ratio) determines the marginal rate of transformation. It is widely assumed that expected excess returns are positively correlated with γ, primarily because more efficient technology produces a higher cash flow, assuming a constant amount of investment. Hansen, Khorrami, and Tourre analyze the recent production-based models and note that long-term uncertainty and the presence of market imperfections determine the 'value' of the productivity shocks [5]. Babaei considers the case of the VNG model with transaction costs and shows that even minor imperfections affect the equilibrium relationship between efficiency and returns [6]. Hence, while the VNG model posits a positive relationship between efficiency and returns, this relationship is dependent on the level of the imperfections present.

2.2. Empirical evidence: TFP and stock returns

None of the empirical studies that have explored the relationship between TFP, and future stock returns is devoid of buyer/seller relationship analysis. Imrohoroğlu and Tüzel establish the fact that there is higher productivity for returns to US firms. They argue that investment frictions (cost and time involved in changing the capital stock of an organization) influence productivity signals and consequently how fast they are reflected in the product price [7]. In relation to the risks of intangible (R&D, personnel) capital, Hiroki, Iwatsubo, and Watkins observe a positive TFP premium for Japanese manufacturers. Still, not all the research is consistent [8]. Ding, Qi, Tang, and Zhao mention the existence of low productivity in the Chinese stock market, contrary to all previous studies, where premium is annualized at 6.6% [9]. This low productivity is a result of lack of risk and is a result of valuation and extreme arbitrage. All the aforementioned studies show that there are cross-country variances, hence the TFP-return relationship is not absolute. The relationship is likely to vary due to market conditions and other relevant industry factors.

2.3. Empirical evidence: TFP and stock returns

There are two reasons some industries seem to have a stronger or even negative relation to TFP. First is the heterogeneity of an industry's capital and potential consumer base. Imrohoroğlu and Tüzel

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argue that the presence of investment frictions hinders the diffusion of the benefits of increased efficiency to less capital-intensive industries [7]. Taussig points out the impact of operational cost flexibility, rigid in transport and elastic in retail, on the speed with which operational efficiency improvements translate to profit improvements [10]. Second, the effects of a Financial Crisis impact the ability to price out risk and the available financing. Zhang and Zhuang argue that increased uncertainty in the economy can reverse the relationship between price and productivity, resulting in low productivity and a high price [11]. Konings et al. argue that government actions to insulate the market from systemic risk during a crisis distort the TFP/return relationship [12]. These effects suggest that the VNG model will only be applicable to low friction and consumers facing industries in normal circumstances, and that during periods of crisis the prediction is likely to reverse.

2.4. Hypothesis development

This paper builds on these themes and puts forth the following three hypotheses:

H1: The relationship between productivity growth in an industry and the associated industry return is positive.

H2: End consumer facing industries, such as retail, will experience a stronger positive price impact from the growth in TFP as compared to capital intensive industries, such as transportation, which will experience a weaker impact.

H3: It is reasonable to assume the Global financial crisis of 2008 will have a negative impact on the price associated with the growth in TFP and the excess return.

An empirical proxy note: Essentially, the VNG model designates γ as the output–input efficiency variable, but in empirical studies, TFP growth (i.e., annual percentage change) is used as a proxy. This adheres to the productivity–asset pricing paradigm, which posits that productivity changes, rather than levels, are better predictors of returns owing to the highly persistent nature of TFP levels. The authors admit that this is a relaxion of the theoretical model, hence the reduced-form regressions are to be interpreted as testing the correlation of efficiency changes to returns in the expected sign rather than testing the level of relationship.

3. Data and variables

This paper analyses the U.S. Retail, Wholesale, Manufacturing, and Transportation & Warehousing industries from 1990 to 2018. These four industries encompass a complete value chain from production to distribution of the economy, are closely integrated, and exhibit high cyclical comovements. They are also sensitive to changes in Total Factor Productivity. This period captures two full business cycles in the U.S., the 2008 global financial crisis, and several seismic market disruptions. Thus, the research can analyze both the pricing effects in a complete horizon as well as the effects during periods of market turmoil. Data on industry returns and the Fama-French three factors were obtained from the Kenneth French Data Library, specifically the 49 Industry portfolios and annual factor datasets. TFP data was sourced from the Bureau of Labor Statistics (BLS) and matched with industry returns using NAICS codes.

The independent variable is TFP growth, which is the annual percentage change in Total productivity, and is used as the proxy of. The dependent variable is Excess return, which is the industry return minus risk-free rate. In addition, this paper introduces MktRF, SMB, and HML as control variables, all of which are the standard Fama-French three factor

The empirical regression model is expressed as follows:

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$$\text{excess return} = \alpha + \beta_\gamma \times \text{TFP growth}_t + \sum_k \lambda_k \cdot X_{k,t} + \varepsilon_t \quad (1)$$

4. Results

4.1. Descriptive statistics

Table 1 shows the average annual TFP growth rates, ranging from 0.83% to 1.26, while the average excess returns range from 10.03% to 11.93%. This shows relatively similar performance for these metrics across sectors. In terms of industry volatility, the Wholesale industry shows the highest standard deviation for TFP growth (2.71) and excess return (29.57), followed by Retail. In contrast, Manufacturing and Transportation/Warehousing are more stable.

These distribution characteristics pave the way to empirically substantiate Hypothesis 1 (a positive correlation between TFP growth and excess returns) and Hypothesis 2 (cross-industry heterogeneity exists). How TFP fluctuates across industries may determine the pricing of assets differently.

Table 1. Data feature analysis

industry	mean	Standard deviation	minimum	maximum
Manufacturing TFP	0.96	1.81	-3.50	5.20
Manufacturing excess return	10.84	26.29	-50.21	64.68
Retail TFP	1.26	1.78	-3.10	5.60
Retail excess return	10.44	20.32	-24.13	56.66
Transportation TFP	0.83	1.59	-1.40	4.50
Transportation excess return	10.03	19.04	-33.97	50.23
Wholesale TFP	1.16	2.71	-4.30	7.20
Wholesale excess return	11.93	29.57	-44.32	92.39

4.2. Time-series regressions by industry

Table 2 displays the regression outcomes of excess returns relative to TFP growth and the Fama-French three factors by industry.

In relation to Hypothesis 1 (H1): The only industry that has a positive and statistically significant coefficient on TFP growth is the retail industry (3.047, p=0.031). This confirms H1 regarding the positive correlation between TFP growth and excess returns. Meanwhile, the other three industries (wholesale, manufacturing, and transportation) do not confirm H1 as their coefficients are statistically insignificant (all p-values > 0.1).

Concerning Hypothesis 2 (H2): Retail being a terminal consumption-based industry is in perfect alignment with H2's expectation that the effect of pricing is stronger in consumer-facing sectors like retail. The fact that transport is a capital-intensive industry results in a negative and insignificant coefficient which conforms to H2's line of reasoning that the effect is weaker in capital- intensive industries. The insignificant results in case of wholesale and manufacturing are also in accord with the industry heterogeneity aspect of H2; wholesale is the intermediary in the distribution chain and manufacturing is more or less dictated by the global supply chains.

H1 is partially supported by Table 2 and is limited to the retail industry. Table 2 also sufficiently substantiates H2 which predicts industry cross-sectional heterogeneity.

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Table 2. Benchmark regression

Variable	Retail	Wholesale	Manufacturing	Transportation
TFP growth	3.047**	-1.105	-1.169	-1.550
	(1.326)	(0.961)	(1.038)	(1.277)
MktRF	0.774***	1.037***	1.113***	0.934***
SMB	0.061	1.616***	1.143***	0.143
HML	-0.309*	0.230	0.398***	0.409***
Constant	0.975	2.168	0.379	2.322
R^2	0.726	0.827	0.882	0.758
N	29	29	29	29

4.3. Subsample analysis: the 2008 financial crisis

Table 3 presents the results for the period prior to the crisis (1990-2007), the period after the crisis (2009-2018), and the interaction term associated with the crisis (post-crisis dummy × TFP growth), which aims to assess Hypothesis H3. This hypothesis suggests that the 2008 financial crisis modified the pricing dynamics associated with TFP growth and excess stock returns.

In the retail sector, the pre-crisis TFP coefficient is significantly positive (4.47, p=0.029), turning negative and insignificant post-crisis (-1.21, p=0.282). The marginally significant negative interaction term (-6.12, p=0.051) confirms a structural break, showing the crisis weakened and reversed TFP's positive pricing effect, supporting H3. For the wholesale sector, the pre-crisis coefficient is insignificant (0.67, p=0.484), while the post-crisis coefficient is significantly negative (-6.47, p=0.031), paired with a highly significant negative interaction term (-7.17, p=0.002). This reveals a post-crisis "low-productivity premium" in wholesale, fully aligning with H3's prediction of a crisis-induced shift in the TFP-returns relationship. By contrast, manufacturing and transport show no significant coefficients in either period, failing to support H3 without contradicting it, as the hypothesis does not require a structural break across all industries.

Overall, H3 receives strong support in the retail and wholesale sectors, confirming the 2008 financial crisis distorted the productivity-returns nexus in these key U. S. industries.

Table 3. Time-divided regression

Industry	Pre-crisis (1990-2007)	Post-crisis (2009-2018)	Interaction term
Retail	4.47**	-1.21	-6.12*
Wholesale	0.67	-6.47**	-7.17***
Manufacturing	0.46	-2.17	-1.31
Transportation	-2.25	1.52	4.07

5. Discussion

The results above show that TFP growth is positively priced only in Retail, that the 2008 crisis creates a negative TFP-return relation in Wholesale, and that Manufacturing and Transport exhibit no significant relation. This section discusses the economic mechanisms behind these patterns and their implications for the VNG framework.

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5.1. Why is TFP pricing exclusive to retail

A large positive coefficient for Retail is predicted by the VNG, but why is this not the case for other industries? The likely reason is Retail's horizontal integration as a direct consumer-facing industry. Efficiency improvements, e.g., better inventory control, better logistics, etc., are converted to higher profit margins and cash flows, which are in turn quickly translated by investors. Conversely, Wholesale, Manufacturing, and Transport operate in B2B settings and have long horizon investments. In B2B settings, the improvements from operational efficiency remain to be captured by customers downstream. In capital-intensive sectors like Transport, productivity improvements take a long time to result in earnings, and the benefits may be competed away. Hiroki, Iwatsubo, and Watkins note that TFP return-link in retail, and other similar intangible intensive industries, is stronger than in the other intensive industries [8]. Taussig relates retail having a high operational flexibility (cost flexibility) as the reason why improvements in operational efficiency are quickly captured as improvements in earnings, whereas, for transport, the rigidity of operational flexibility leads to a significant delay of improvements in operational efficiency and subsequently the earnings [10]. Hansen, Khorrami, and Tourre formalized the fact that in economies with a high degree of frictions, productivity improvements go unrewarded for a long and uncertain time [5]. Therefore, the VNG model prediction holds true only under low frictions.

5.2. The crisis-induced reversal: understanding the low-productivity premium in wholesale

The negative TFP–return relationship in Wholesale post-2008 is inconsistent with the VNG prediction but aligns with the case of crisis-induced sign reversal. Zhang and Zhuang show that increased macroeconomic uncertainty can alter the sign of the premium associated with productive pricing: in the presence of heightened uncertainty, they state, investors tend to relocate their capital in ways that produce a low- productivity premium [11]. Ding, Qi, Tang, and Zhao note a low-productivity premium of 6.6% annually in the Chinese stock market and link this to mispricing and a lack of arbitrage [9]. Konings et al. propose a similar theory: as a result of the crisis, temporary government interventions, such as small business financing and industry bailouts, protect highly inefficient firms from market pressure, allowing the firms to survive and provide positive but low returns [12]. Babaei argues that highly increased transaction costs, particularly during a crisis, can disrupt the relationship between efficiency and returns [6]. The highly significant interaction term ($p = 0.002$) confirms this structural break beyond a reasonable doubt.

5.3. What explains the absence of TFP pricing in the manufacturing and transport sectors

The absence of identifiable factors in Manufacturing and Transport sectors provides valuable insight into the limitations of the VNG model. Manufacturing has a significant degree of exposure to global supply chain interconnectivity, trade regulations, and currency fluctuations, which makes the TFP measure at a single-country level a poor signal. Transport, on the other hand, has a high capital intensity and large assets with long durations (e.g. aircraft, ships, and rail systems). According to Taussig, in these sectors, cost flexibility and structural operating costs are low, while significant competition within the sector drives firms to transfer most of the cost savings from operational efficiencies to their customers through reduced pricing [10]. As a consequence, changes in TFP within these sectors are either expected, postponed, or not captured within the profit margins of shareholders, and therefore are highly unlikely to be priced factors. This highlights the fact that asset

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pricing models need to incorporate market and technological frictions that are specific to each industry.

5.4. What do these findings mean for the VNG framework

Collectively, these insights suggest that, while the VNG model has successfully predicted specific outcomes in consumer-facing industries (Retail) during typically stable periods, the reverse is true for certain sectors (Wholesale) during turbulent periods, and the model completely fails to apply to capital-intensive industries or sectors with high levels of global economic interdependency (Manufacturing and Transport). In terms of the VNG framework, future theoretical developments should aim to incorporate state-contingent frictions, financing gaps, and regulatory constraints. From an empirical perspective, data on firm-level TFP at higher frequency would enable the testing of the two-factor framework proposed by the VNG model. This is something that annual data at the industry level is not able to fully achieve.

6. Conclusion

This paper examines the VNG production-based asset pricing model and tests the theory that production efficiency should be a priced factor. In this paper, TFP growth is used as the proxy for productivity and is applied to four U. S. industries between the years 1990 to 2018. This paper concludes with three important findings.

First, for the entire sample, only the Retail industry had a positive significant TFP-return relation and therefore, is consistent with VNG prediction. Second, the 2008 Financial Crisis changed this relation significantly: Retail's positive effect vanished post-crisis, while Wholesale experienced a significantly low productivity premium (negative TFP-return relation). This post-crisis low productivity premium in Wholesale is also consistent with other documented markets, e.g., China. Third, Manufacturing and Transport had no significant TFP pricing in any time period.

This paper provides three contributions to existing literature. First, it provides the VNG model and complements it with the risk-based mechanism. Second, it shows that pricing productivity can be reversed when there is a significant crisis. Lastly, it outlines clear implications for specific sectors' investment strategies during financial crises.

This paper also has shortcomings. Analysis is confined to the industry level; access to firm level data may be helpful. This sample is also only up this point in time (2018) and therefore excludes any post-COVID dynamics. Future studies can build upon this, to extend the sample, incorporate firm level TFP, and see whether the patterns here hold true in other countries and in other crises.

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