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”A Production-based Economic Explanation for the Gross Pro tability Premium”

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A Production-based Economic Explanation for the Gross Profitability Premium

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Motivation

- Recent studies document that firms with high gross profitability earn higher returns than low profitability firms (Novy-Marx, 2013);
- This finding has a substantial impact on asset pricing research and motivated the inclusion of the profitability premium as a pricing factor (Hou, Xue, and Zhang, 2015, Fama and French, 2015);
- More profitable firms look more like growth firms (low BM) and less profitable firms look more like value firms (high BM), contradicting the well-established value premium.

Main contribution

In this paper, we provide a production-based explanation for the gross profitability premium:

- A novel hedging effect from intermediate inputs (variable costs):

$$\text{Gross Profitability (GP/A)} = \frac{\text{Revenue - Variable Cost}}{\text{Total Asset}}$$

- Empirically, both price and cost of intermediate inputs are more procylical than those of the revenues;
- On average, intermediate inputs offer a hedge to business cycle variations;
- In the cross section, more profitable firms have higher revenue-to-variable-cost ratio and lower hedging effect, leading to a positive gross profitability premium.

Main contribution

We illustrate this mechanism in a static production-based asset pricing model;

- CES production function between capital and intermediate inputs;
- Production subject to aggregate demand shocks and idiosyncratic productivity shocks;
- Analytically, a positive gross profitability premium when
  1. Elasticity of substitution b/t capital and intermediate inputs is low;
  2. Price is more procyclical for intermediate inputs than output;

A dynamic extension of the model with capital accumulation and investment-specific technology shocks quantitatively generates:

- Gross profitability premium of about 3.1% (3.69% in the data) and value premium about 3.4% (5.43% in the data);
- A negative correlation of -0.27 (-0.5 in the data) between gross profitability premium and value premium;
- Gross profitability being the other side of value;
- Failure of the unconditional CAPM.

Literature

- Explanations for the profitability premium
  - Risk-based explanations:
    - Kogan and Papanikolaou (2013), Ma and Yan (2015)
  - Behavioral explanations:
    - Wang and Yu (2015), Lam, Wang, and Wei (2014), Bouchaud, Krueger, Landier, and Thesmar (2016)
- Explanations for the value premium
  - Berk, Green, Naik (1999), Zhang (2005), Carlson, Fisher, and Giammarino (2004), Cooper (2006), Lettau and Wachter (2007), Kogan and Papanikolaou (2014), Choi (2013), Donangelo (2018), etc.
- Operating leverage
  -Novy-Marx (2010), Carlson, Fisher, and Giammarino (2004), Zhang (2005), Favilukis and Lin (2015), Favilukis, Lin, and Zhao (2017), Petrosky-Nadeau, Zhang, Kuhen (2018), Donangelo, Gourio, Kehrig, and Palacios (2017)

A static model

- One period problem, only assets in place;
- CES production function, so gross profits π are

$$\pi = \max_{E} \left\{ X \left[(ZE)^{\frac{\eta-1}{\eta}} + K^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} - P \times E \right\}$$

  where K is capital, E is intermediate inputs, P is the purchase price of E, η is the elasticity of substitution between capital and intermediate inputs, X represents the aggregate demand, and Z is the idiosyncratic input-augmenting productivity;

- FOC implies:

$$\text{GP/A} \equiv \frac{\pi}{K} = X \left[\left(\frac{ZE}{K} \right)^{\frac{\eta-1}{\eta}} + 1 \right]^{\frac{1}{\eta-1}}$$

  $\Rightarrow$ GP/A increases with Z.

A static model, Cont.

- The exposure of gross profit (π) to X shocks:

$$\beta_X \equiv \frac{\partial \log \pi}{\partial \log X} = \frac{\partial \log P}{\partial \log X} + \left(1 - \frac{\partial \log P}{\partial \log X}\right) \left[\left(\frac{ZE}{K}\right)^{\frac{\eta-1}{\eta}} + 1\right]$$

- It can be shown:

$$\frac{\partial \beta_X}{\partial \log Z} = (\eta - 1) \left(1 - \frac{\partial \log P}{\partial \log X}\right) \left(\frac{ZE}{K}\right)^{\frac{\eta-1}{\eta}} \left[1 + \left(\frac{ZE}{K}\right)^{\frac{\eta-1}{\eta}}\right].$$

$\Rightarrow$ A positive gross profitability premium if

1. $\eta > 1$ and $\frac{\partial \log P}{\partial \log X} < 1$; or
2. $\eta < 1$ and $\frac{\partial \log P}{\partial \log X} > 1$.

Intuition

$$\begin{aligned}\text{Gross profit} &= \text{Rev} - \text{COGS} \\ &= \left\{ X \left[(ZE^*)^{\frac{\eta-1}{\eta}} + K^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} - P \times E^* \right\}\end{aligned}$$

- When $\frac{\partial \log P}{\partial \log X} > 1$, $\beta_X(\text{Rev}) < \beta_X(\text{COGS})$;
- On average, variable cost generates a hedging effect to X shocks;
- Cross-sectional heterogeneity: when $\eta < 1$, E is "sticky", revenue increases more than variable cost in response to a positive Z shock;
- High Z (more profitable) firms have higher Rev/COGS ratio, and less affected by the hedging effect than low Z (less profitable) firms;
- High Z firms have higher exposures to X shocks and higher expected returns than low Z firms;

$\Rightarrow$ Positive gross profitability premium.

Aggregate demand elasticity of input price and quantity

Panel A: Summary statistics

	ΔP(Output)	ΔP(Input)	ΔQ(Output)	ΔQ(Input)
Mean (%)	3.35	3.34	3.07	3.03
Std (%)	2.83	3.68	2.81	3.86

Panel B: Elasticity of intermediate input price and quantity w.r.t. output prices

	ΔP(Input)	ΔQ(Input)
β(ΔP(Output))	1.27	-0.27
t-stat	(25.43)	(-1.40)

*Data from BEA GDP-by-industry account, 1947-2014

- Input price is highly procylical ($\frac{\partial \log P}{\partial \log X} > 1$);
- Input quantity is "sticky" ($\eta < 1$).

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Estimates of η

Model predicts: $GP/A = X\left(\frac{1}{GM}\right)^{\frac{1}{\eta-1}}$, η can be estimated from FMB regression:

$$\log GM_{it} = a_t + (1-\eta_t)\times \log GP/A_{it} + \epsilon_{it}$$

	10 GP/A	10 BM	10 GP/A + 10 BM
η	0.612	0.371	0.573
se	0.031	0.035	0.025

Industry	η	se
Agriculture, forestry, fishing, and hunting	0.738	0.037
Arts, entertainment, recreation, etc	0.708	0.032
Construction	0.751	0.037
Educational services, health care, and social assistance	0.510	0.026
Finance, insurance, real estate, rental, and leasing	0.878	0.027
Information	0.642	0.008
Manufacturing	0.534	0.020
Mining	0.690	0.031
Other services, except government	0.733	0.032
Professional and business services	0.607	0.023
Retail trade	0.624	0.021
Transportation and warehousing	0.696	0.046
Utilities	0.743	0.067
Wholesale trade	0.627	0.035

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Additional implications

When $\frac{\partial \log P}{\partial \log X} > 1$ and $\eta < 1$, firms' responses to an aggregate demand shock and an idiosyncratic productivity shock are very different:

- A positive aggregate demand shock $\Rightarrow$ Rev $\uparrow$ and COGS $\uparrow\uparrow$

  Prediction 1: At aggregate level, Vol(Rev) $>$ Vol(GP)

- A positive idiosyncratic shock $\Rightarrow$ Rev $\uparrow\uparrow$ and COGS $\uparrow$

  Prediction 2: At firm level, Vol(Rev) $<$ Vol(GP)

Sales growth and gross profits growth

Panel A: Sales growth and gross profits growth at the aggregate level

Panel A1

Summary	ΔASale	ΔAGP
Mean (%)	3.16	3.31
Std (%)	5.75	4.99

Panel A2

Cyclicality of AGP	
b	0.75
t-stat	(14.27)

Panel B: Sales growth and gross profits growth at the firm level

Panel B1

Summary	ΔSale	ΔGP
Mean (%)	7.49	7.06
Std (%)	21.07	26.73

Panel B2

Cyclicality of GP	
b	1.14
t-stat	(17.73)

⇒ The opposite patterns in responses to aggregate and idiosyncratic shocks are key for the GP/A premium.

Sales growth and gross profits growth

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Panel B: Sales growth and gross profits growth at the firm level

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Panel B2

Cyclicality of GP	
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t-stat	(17.73)

$\Rightarrow$ The opposite patterns in responses to aggregate and idiosyncratic shocks are key for the GP/A premium.

A dynamic extension: Motivation

- The static model describes the intuition for the gross profitability premium in a parsimonious way;
- But it implies that high Z firms have high V and high β_X
  $\Rightarrow$ A negative value premium!!
- Furthermore, one-factor model structure implies CAPM holds;
- We provide a dynamic extension of the model to quantitatively explain both gross profitability premium and value premium.

A dynamic extension: Setup

- The basic production unit is projects. Each project uses one unit of capital and E_{jt} units of intermediate inputs;

$$\pi_{jt} = \max_{E_{jt}} \left\{ X_t \left[(Z_{jt} E_{jt} Y_t)^{\frac{\eta-1}{\eta}} + Y_t^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} - P_t Y_t E_{jt} \right\}$$
$$= Y_t \max_{E_{jt}} \left\{ X_t \left[(Z_{jt} E_{jt})^{\frac{\eta-1}{\eta}} + 1 \right]^{\frac{\eta}{\eta-1}} - P_t E_{jt} \right\}$$

  where Y_t is aggregate productivity shock;

- Capital accumulation:

$$K_{jt+1} = (1-\delta) K_{jt} + \delta S_t A_{jt} K_{jt},$$

  where K_{jt} is the number of projects, S_t and A_{jt} measure the aggregate and firm-specific intensity of new project arrivals.

A dynamic extension: Setup

- Firm value can be written recursively as:

$$V_{jt} = K_{jt}\pi_{jt} + E_t[M_{t+1}V_{jt+1}]$$

subject to profit-maximizing condition and law of motion for capital

- Exogenous processes:

$$x_{t+1} = \rho_x x_t + (1-\rho_x)\bar{x} + \sigma_x \epsilon^x_{t+1}$$

$$s_{t+1} = \rho_s s_t + (1-\rho_s)\bar{s} + \sigma_s \epsilon^s_{t+1}$$

$$\Delta y_{t+1} = \sigma_y \epsilon^y_{t+1}$$

$$\log P_t = \log p_0 + p_1 \log X_t,$$

$$z_{jt+1} = \rho_z z_{jt} + (1-\rho_z)\bar{z} + \sigma_z \epsilon^z_{jt+1} + \mu_z$$

$$a_{jt+1} = \rho_a a_{jt} + \sigma_a \epsilon^a_{jt+1}$$

$$\rho_{az} \equiv \text{Corr}(\epsilon^z_{jt+1}, \epsilon^a_{jt+1}) > 0$$

- Pricing kernel:

$$M_{t+1} = \exp\left(-r_f - \gamma_x\sigma_x\epsilon^x_{t+1} - \gamma_y\sigma_y\epsilon^y_{t+1} - \gamma_s\sigma_s\epsilon^s_{t+1} - \frac{1}{2}\gamma_x^2\sigma_x^2 - \frac{1}{2}\gamma_y^2\sigma_y^2 - \frac{1}{2}\gamma_s^2\sigma_s^2\right)$$

A dynamic extension: Calibration

Parameter	Description	Value
γ_x	Price of risk for aggregate demand shocks	15
γ_y	Price of risk for aggregate productivity shocks	6.5
γ_s	Price of risk for aggregate investment shocks	-10
η	Elasticity of substitution between capital and inputs	0.3
δ	Depreciation rate	0.01
r_f	Risk-free rate	0.25%
$\bar{x}$	Unconditional aggregate demand	0
ρ_x	Persistence of aggregate demand shocks	0.98
σ_x	Conditional volatility of aggregate demand shocks	0.04
σ_y	Conditional volatility of aggregate productivity shocks	0.027
$\bar{s}$	Unconditional aggregate investment opportunity	-0.146
ρ_s	Persistence of aggregate investment shocks	0.9685
σ_s	Conditional volatility of aggregate investment shocks	0.026
$\bar{z}$	Unconditional idiosyncratic productivity	1.1
ρ_z	Persistence of idiosyncratic productivity shocks	0.97
σ_z	Conditional volatility of idiosyncratic productivity shocks	0.075
ρ_a	Persistence of idiosyncratic investment shocks	0.98
σ_a	Conditional volatility of idiosyncratic investment shocks	0.107
ρ_{az}	Correlation between z shocks and a shocks	0.18
p_0	Logarithm of the level of intermediate inputs price	0.588
p_1	Cyclicality of intermediate inputs price w.r.t. aggregate demand	1.39
ϕ	Leverage ratio	1.67

A dynamic extension: Moments

Moment	Data	Model
Average annual aggregate GP/A	0.24	0.25
AR(1) of aggregate annual GP/A	0.87	0.92
Average book-to-market ratio	0.53	0.44
AR(1) of aggregate book-to-market	0.89	0.89
Average annual aggregate investment rate	11.4%	11.1%
Standard deviation of annual aggregate investment rate	1%	1%
AR(1) of annual aggregate investment rate	0.73	0.72
Average aggregate sales - aggregate variable costs ratio	1.44	1.50
Vol. of agg. sales - agg. variable costs ratio	0.05	0.05
Vol. of agg. variable costs growth/vol. of agg. sales growth	1.12	1.15
Corr. b/w agg. sales growth and agg. variable costs growth	0.99	0.99
Vol. of firm variable costs growth/Vol. of firm sales growth	0.99	0.91
Value-weighted annual market premium	6.47%	8.87%
Value-weighted annual market volatility	16.96%	18.33%
Equally-weighted annual market premium	10.9%	9.42%
Equally-weighted annual market volatility	26.03%	18.13%
Volatility of monthly firm-level stock returns	12.6%	10.9%

A dynamic extension: Portfolio characteristics

GP/A portfolios

	GP/A	logBM	GM	Z	A
Lo	0.05	-0.93	0.09	0.71	-0.36
2	0.16	-1.02	0.23	0.95	-0.28
3	0.24	-1.09	0.30	1.10	-0.23
4	0.33	-1.14	0.37	1.25	-0.18
Hi	0.47	-1.24	0.47	1.49	-0.10

Book-to-market portfolios

	GP/A	logBM	GM	Z	A
Lo	0.31	-1.56	0.35	1.24	0.52
2	0.29	-1.21	0.33	1.19	0.04
3	0.26	-1.05	0.31	1.13	-0.24
4	0.23	-0.90	0.28	1.05	-0.52
Hi	0.16	-0.70	0.21	0.89	-0.94

- Gross margin is higher for High GP/A and growth stocks;
- Gross profitability looks like the other side of value;
- GP/A portfolios mainly sorts on Z; BM portfolios mainly sorts on A.

A dynamic extension: Portfolio returns and AP tests

GP/A portfolios

	Lo	2	3	4	Hi	Hi-Lo
Mean	6.87	7.74	8.39	9.09	10.00	3.13
Std	16.95	17.08	17.15	17.23	17.45	5.59
α	-1.52	-0.72	-0.11	0.56	1.36	2.88
	(-3.15)	(-1.51)	(-0.23)	(1.15)	(2.77)	(3.67)
MKT	0.99	0.99	1.00	1.00	1.01	0.03
α	-2.00	-0.92	-0.17	0.68	1.79	3.79
	(-4.11)	(-1.89)	(-0.35)	(1.34)	(3.58)	(4.84)
MKT	1.00	1.00	1.00	1.00	1.00	0.00
HML	0.11	0.05	0.01	-0.03	-0.10	-0.20

Book-to-market portfolios

	Lo	2	3	4	Hi	Hi-Lo
Mean	6.45	8.78	9.42	9.89	9.86	3.40
Std	18.46	17.01	16.67	16.42	16.18	7.32
α	-2.64	0.31	1.12	1.73	1.86	4.50
	(-4.50)	(0.76)	(2.80)	(4.07)	(3.90)	(4.59)
MKT	1.07	1.00	0.97	0.96	0.94	-0.13
α	-0.12	-0.26	0.17	0.48	-0.12	0.00
	(-0.56)	(-0.68)	(0.48)	(1.43)	(-0.56)	
MKT	1.00	1.01	1.00	0.99	1.00	0.00
HML	-0.56	0.13	0.21	0.28	0.44	1.00

A dynamic extension: Portfolio returns and AP tests

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MKT	1.00	1.01	1.00	0.99	1.00	0.00
HML	-0.56	0.13	0.21	0.28	0.44	1.00

GP/A portfolios

	Lo	2	3	4	Hi	Hi-Lo
$\beta(X)$	0.05	0.09	0.11	0.14	0.18	0.13
	(4.99)	(7.94)	(10.12)	(12.39)	(15.67)	(8.49)
$\beta(Y)$	1.68	1.68	1.68	1.68	1.68	0.00
	(107.99)	(103.09)	(101.96)	(98.46)	(96.55)	(0.17)
$\beta(S)$	0.62	0.64	0.65	0.66	0.69	0.06
	(39.01)	(37.99)	(37.73)	(37.39)	(38.12)	(2.59)

Book-to-market Portfolios

	Lo	2	3	4	Hi	Hi-Lo
$\beta(X)$	0.12	0.13	0.13	0.12	0.09	-0.02
	(8.41)	(14.66)	(16.63)	(17.26)	(14.84)	(-1.62)
$\beta(Y)$	1.68	1.68	1.68	1.68	1.68	0.00
	(80.60)	(126.62)	(145.28)	(159.42)	(179.85)	(0.21)
$\beta(S)$	0.95	0.65	0.55	0.47	0.38	-0.57
	(44.07)	(47.71)	(45.94)	(44.00)	(39.89)	(-24.46)

- The GP/A premium loads strongly on aggregate demand (X) shocks;
- The value premium loads strongly on investment (S) shocks ;
- Portfolio exposures to aggregate productivity (Y) shocks are flat;
- A positive ρ_{az} gives rise to a negative correlation between GP/A premium and value premium.

A dynamic extension: Portfolio risk exposures

GP/A portfolios

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- The value premium loads strongly on S shocks;
- Portfolio exposures to Y shocks are flat;
- A positive ρ_{az} gives rise to a negative correlation between GP/A premium and value premium.

Conclusion

- A production-based explanation for the gross profitability premium;
  - A novel hedging effect from intermediate inputs;
  - More profitable firms have higher exposure to the aggregate demand shock than less profitable firms due to heterogeneity in hedging effect;
- A dynamic extension offers a unified interpretation for gross profitability premium and value premium;
- It reproduces the coexistence of gross profitability premium and value premium, their negative correlation, and the failure of CAPM.