Supplemental Appendix

The Value of Software

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Appendix Table of Contents

Appendix A Additional Figures and Tables

Table A.1. **List of Sub-Industries Used to Identify Software Companies**

RBICS industry name		
Asset Management Software	Government and Public Service Industry Software	Other Games Software
Automotive Enterprise Management Software	Handheld and Smart Phone Games Software	Other Handheld and Smart Phone Software
Automotive Industry Software	Healthcare Management Software	Other Healthcare and Pharma Industry Software
Business Intelligence Software	Healthcare Operations Support Software	Other Network Software
Business Planning and Control ERP Software	Home and Office Multimedia Software	Other Telecommunications Industry Software
Commercial Bank and Credit Union Software	Hospitality Industry Software	Patient Data Management Software
Communications Infrastructure Software	Human Resources ERP Software	Payment Processing Software
Computer Aided Design (CAD) Software	IC-Level Electronic Design Software	Print and Prepress Industry Software
Computer and Software Stores	IC-Level Intellectual Property Software Libraries	Productivity Software
Console Games Software	Insurance Software	Real Estate and Construction Industry Software
Customer Service Software	Investment Management/Brokerage Software	Retail Industry Software
Data Storage Infrastructure Software	Legal, Tax and Accounting Industry Software	Sales Force Automation (SFA) Software
Diversified Content Management Software	Manufacturing Industry Software	Software Design and Engineering Consulting
Diversified Customer Relationship Software	Mapping/Geographic Information Systems Software	Software Development Software
Diversified Enterprise Resource Planning Software	Marketing CRM Software	Software Distributors
Diversified IT Infrastructure Software	Media and Entertainment Industry Software	Supply Chain ERP Software
Document Management Software	Mobile Platform Applications Software	Telecommunications Customer Relationship Software
Drug Development Software	Multi-Type Home and Office Software	Telecommunications Operations Support Software
E-Signature Software	Multimedia Design and Engineering Software	Trading Software
Educational Software	Multiple Industry-Specific Software	Transportation Industry Software
Embedded Automotive Software	Network Administration Software	Utilities Industry Software
Energy Industry Software	Network Security Access Policy Software	Vehicle Autonomous Control Software
Enhanced Telecommunications Services Software	Network Security Software	Virtual Reality Design and Engineering Software
Enterprise Middleware Software	Not-For-Profit Industry Software	Web Development Software Makers
Enterprise Security Management Software	Online Game Websites and Software	Web Navigation Sites and Software
Financial and Compliance ERP Software	Operating Systems Software	Web Portal Sites and Software
General Enterprise Management Software	Other Design and Engineering Software	Web Search Sites and Software
General and Mixed-Type Software	Other Finance Industry Software	

Notes: This table lists each of the FactSet Revere Business Industry Classification System (RBICS) sub-industries used in our sample construction. We select all sub-industries containing the word *software* and for which the main business relates to creating and selling software or software platforms. There are 1,207 total firms spanning 83 distinct RBICS sub-industries.

Table A.2. **Largest Software Companies**

		Market cap.	Cumulative market share relative to				Market Cap	Cumulative market share relative to	
Year	Name	(billions)	Softw. market cap.	Total market cap.	Year	Name	(billions)	Softw. market cap.	Total market cap.
1996	Microsoft Corp	98.98	47.95	1.16	1997	Microsoft Corp	156.00	54.88	1.41
1996	CA Inc	18.15	56.74	1.37	1997	CA Inc	28.98	65.07	1.67
1996	PTC Inc	6.55	59.91	1.45	1997	Peoplesoft Inc.	8.73	68.14	1.75
1996	Peoplesoft Inc.	5.16	62.41	1.51	1997	BMC Software Inc	6.74	70.51	1.81
1996	Netscape Communications Corp	5.00	64.83	1.57	1997	PTC Inc	6.05	72.64	1.86
1996	BMC Software Inc	4.18	66.86	1.62	1997	McAfee Inc	3.70	73.94	1.89
1996	Cadence Design Systems Inc	3.27	68.44	1.66	1997	Altaba Inc	3.12	75.04	1.92
1996	Novell Inc.	3.26	70.02	1.70	1997	Adobe Inc	2.84	76.04	1.95
1996	Ascential Software Corp	3.07	71.51	1.73	1997	Edwards J D & Co	2.74	77.00	1.97
1996	Adobe Inc	2.67	72.80	1.76	1997	SunGard Data Systems Inc	2.68	77.94	2.00
1998	Microsoft Corp	342.56	63.53	2.52	1999	Microsoft Corp	602.43	48.74	3.42
1998	Altaba Inc	23.38	67.87	2.69	1999	Altaba Inc	115.27	58.07	4.07
1998	CA Inc	22.94	72.12	2.86	1999	CA Inc	37.70	61.12	4.28
1998	BMC Software Inc	9.67	73.92	2.93	1999	VERITAS Software Co	37.09	64.12	4.49
1998	McAfee Inc	9.15	75.61	3.00	1999	Ariba Inc	32.60	66.76	4.68
1998	Cadence Design Systems Inc	6.60	76.84	3.05	1999	BMC Software Inc	19.37	68.33	4.79
1998	Novell Inc.	6.12	77.97	3.09	1999	Siebel Systems Inc	15.53	69.58	4.88
1998	Netscape Communications Corp	6.05	79.09	3.14	1999	I2 Technologies Inc	15.00	70.80	4.96
1998	Peoplesoft Inc.	4.51	79.93	3.17	1999	Compuware Corp	13.33	71.88	5.04
1998	PTC Inc	4.34	80.73	3.20	1999	Novell Inc.	13.04	72.93	5.11

Table A.2 – continues in the next page

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Year	Name	Market cap. (billions)	Cumulative market share relative to Softw. market cap.	Cumulative market share relative to Total market cap.	Year	Name	Market Cap (billions)	Cumulative market share relative to Softw. market cap.	Cumulative market share relative to Total market cap.
2000	Microsoft Corp	231.29	37.23	1.43	2001	Microsoft Corp	357.95	59.12	2.51
2000	VERITAS Software Co	34.38	42.76	1.65	2001	CA Inc	19.87	62.40	2.65
2000	Siebel Systems Inc	29.92	47.58	1.83	2001	VERITAS Software Co	18.13	65.39	2.78
2000	Bea Systems Inc	25.88	51.74	1.99	2001	Siebel Systems Inc	13.07	67.55	2.87
2000	I2 Technologies Inc	22.07	55.30	2.13	2001	Peoplesoft Inc.	12.29	69.58	2.96
2000	Altaba Inc	16.88	58.01	2.23	2001	Altaba Inc	10.21	71.27	3.03
2000	Adobe Inc	14.02	60.27	2.32	2001	Intuit Inc.	9.07	72.76	3.09
2000	Ariba Inc	13.54	62.45	2.41	2001	SunGard Data Systems Inc	8.08	74.10	3.15
2000	CA Inc	11.56	64.31	2.48	2001	Adobe Inc	7.33	75.31	3.20
2000	Peoplesoft Inc.	10.70	66.03	2.54	2001	Bea Systems Inc	6.18	76.33	3.24
2002	Microsoft Corp	276.63	58.51	2.44	2003	Microsoft Corp	295.29	46.67	1.97
2002	Oracle Corp	56.91	70.55	2.95	2003	Oracle Corp	69.16	57.60	2.43
2002	Altaba Inc	9.73	72.60	3.03	2003	Altaba Inc	29.75	62.30	2.63
2002	Intuit Inc.	9.63	74.64	3.12	2003	VERITAS Software Co	15.88	64.82	2.73
2002	CA Inc	7.74	76.28	3.19	2003	CA Inc	15.83	67.32	2.84
2002	SunGard Data Systems Inc	6.67	77.69	3.24	2003	Intuit Inc.	10.49	68.98	2.91
2002	VERITAS Software Co	6.44	79.05	3.30	2003	Adobe Inc	9.31	70.45	2.97
2002	Peoplesoft Inc.	5.74	80.26	3.35	2003	Peoplesoft Inc.	8.20	71.74	3.02
2002	Adobe Inc	5.73	81.48	3.40	2003	SunGard Data Systems Inc	7.91	72.99	3.08
2002	Bea Systems Inc	4.71	82.47	3.44	2003	Siebel Systems Inc	6.94	74.09	3.12

Table A.2 – continues in the next page

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Year	Name	Market cap. (billions)	Cumulative market share relative to: Softw. market cap.	Cumulative market share relative to: Total market cap.	Year	Name	Market Cap (billions)	Cumulative market share relative to: Softw. market cap.	Cumulative market share relative to: Total market cap.
2004	Microsoft Corp	290.72	41.04	1.71	2005	Microsoft Corp	270.22	36.44	1.50
2004	Oracle Corp	71.69	51.15	2.14	2005	Alphabet Inc	82.76	47.60	1.96
2004	Altaba Inc	52.13	58.51	2.44	2005	Oracle Corp	63.03	56.10	2.31
2004	Electronic Arts Inc	18.93	61.19	2.56	2005	Altaba Inc	56.03	63.65	2.62
2004	Alphabet Inc	18.42	63.79	2.67	2005	Adobe Inc	21.86	66.60	2.74
2004	CA Inc	18.19	66.35	2.77	2005	Gen Digital Inc	18.24	69.06	2.85
2004	Adobe Inc	15.32	68.52	2.86	2005	CA Inc	16.32	71.26	2.94
2004	VERITAS Software Co	12.08	70.22	2.93	2005	Electronic Arts Inc	15.85	73.40	3.02
2004	Peoplesoft Inc.	9.95	71.63	2.99	2005	SunGard Data Systems Inc	10.44	74.86	3.08
2004	Autodesk Inc	8.71	72.86	3.04	2005	VERITAS Software Co	10.43	76.40	3.14
2006	Microsoft Corp	291.94	36.61	1.43	2007	Microsoft Corp	332.11	34.33	1.60
2006	Alphabet Inc	104.84	49.75	1.95	2007	Alphabet Inc	163.26	51.20	2.38
2006	Oracle Corp	88.82	60.89	2.39	2007	Oracle Corp	115.98	63.19	2.94
2006	Altaba Inc	34.74	65.25	2.56	2007	Altaba Inc	31.10	66.41	3.09
2006	Adobe Inc	24.20	68.28	2.68	2007	Adobe Inc	24.31	68.92	3.20
2006	Gen Digital Inc	19.34	70.71	2.77	2007	Electronic Arts Inc	18.52	70.83	3.29
2006	Electronic Arts Inc	15.61	72.66	2.85	2007	Gen Digital Inc	13.64	72.24	3.36
2006	CA Inc	11.87	74.15	2.91	2007	CA Inc	12.86	73.57	3.42
2006	Intuit Inc.	10.64	75.49	2.96	2007	Autodesk Inc	11.49	74.76	3.48
2006	Autodesk Inc	9.36	76.66	3.00	2007	Intuit Inc.	10.52	75.85	3.53

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		Market cap.	Cumulative market share relative to				Market Cap	Cumulative market share relative to	
Year	Name	(billions)	Softw. market cap.	Total market cap.	Year	Name	(billions)	Softw. market cap.	Total market cap.
2008	Microsoft Corp	172.80	32.33	1.41	2009	Microsoft Corp	268.56	32.14	1.70
2008	Oracle Corp	89.47	49.07	2.14	2009	Alphabet Inc	151.03	50.21	2.66
2008	Alphabet Inc	73.86	62.89	2.75	2009	Oracle Corp	122.93	64.92	3.44
2008	Altaba Inc	16.98	66.07	2.89	2009	Altaba Inc	23.59	67.75	3.59
2008	Gen Digital Inc	11.30	68.18	2.98	2009	Adobe Inc	19.22	70.05	3.71
2008	Activision Blizzard Inc	11.23	70.28	3.07	2009	Gen Digital Inc	14.42	71.77	3.80
2008	Adobe Inc	11.20	72.38	3.16	2009	Activision Blizzard Inc	13.89	73.44	3.89
2008	CA Inc	9.53	74.16	3.24	2009	CA Inc	11.57	74.82	3.97
2008	Bea Systems Inc	7.93	75.19	3.28	2009	Baidu Inc	10.82	76.12	4.03
2008	Intuit Inc.	7.61	76.61	3.34	2009	Intuit Inc.	9.73	77.28	4.10
2010	Microsoft Corp	234.53	25.73	1.28	2011	Microsoft Corp	217.82	24.80	1.24
2010	Oracle Corp	158.14	43.07	2.15	2011	Alphabet Inc	167.85	43.92	2.19
2010	Alphabet Inc	144.70	58.95	2.94	2011	Oracle Corp	128.91	58.60	2.93
2010	Baidu Inc	26.18	61.82	3.08	2011	Baidu Inc	31.59	62.19	3.10
2010	Altaba Inc	21.77	64.21	3.20	2011	Altaba Inc	19.58	64.42	3.22
2010	Salesforce Inc	17.34	66.11	3.30	2011	Intuit Inc.	15.63	66.20	3.30
2010	Adobe Inc	15.45	67.80	3.38	2011	Activision Blizzard Inc	13.96	67.79	3.38
2010	Intuit Inc.	15.31	69.48	3.46	2011	Adobe Inc	13.90	69.37	3.46
2010	Activision Blizzard Inc	14.72	71.10	3.54	2011	Salesforce Inc	13.80	70.95	3.54
2010	Citrix Systems Inc	12.83	72.50	3.61	2011	Gen Digital Inc	11.42	72.25	3.61

Table A.2 – continues in the next page

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		Market cap.	Cumulative market share relative to				Market Cap	Cumulative market share relative to	
Year	Name	(billions)	Softw. market cap.	Total market cap.	Year	Name	(billions)	Softw. market cap.	Total market cap.
2012	Microsoft Corp	223.67	23.18	1.13	2013	Alphabet Inc	313.04	22.78	1.22
2012	Alphabet Inc	189.19	42.79	2.08	2013	Microsoft Corp	310.50	45.38	2.44
2012	Oracle Corp	157.75	59.13	2.88	2013	Oracle Corp	172.07	57.90	3.11
2012	Baidu Inc	27.54	61.99	3.02	2013	Baidu Inc	49.07	61.47	3.30
2012	Salesforce Inc	23.87	64.46	3.14	2013	Altaba Inc	41.02	64.46	3.46
2012	Altaba Inc	22.19	66.76	3.25	2013	Salesforce Inc	33.28	66.88	3.59
2012	Adobe Inc	18.62	68.69	3.35	2013	Adobe Inc	29.72	69.04	3.71
2012	Intuit Inc.	17.61	70.52	3.43	2013	Intuit Inc.	21.74	70.62	3.79
2012	Cerner Corp	13.34	71.90	3.50	2013	Cerner Corp	19.16	72.02	3.87
2012	Gen Digital Inc	12.97	73.24	3.57	2013	Gen Digital Inc	16.31	73.20	3.93
2014	Microsoft Corp	381.73	23.73	1.36	2015	Alphabet Inc	489.26	26.37	1.84
2014	Alphabet Inc	331.25	44.32	2.54	2015	Microsoft Corp	439.68	50.06	3.50
2014	Oracle Corp	197.48	56.59	3.25	2015	Oracle Corp	153.47	58.33	4.08
2014	Baidu Inc	63.16	60.52	3.47	2015	Alibaba Group Holding Ltd	81.06	62.70	4.39
2014	Alibaba Group Holding Ltd	51.77	63.74	3.66	2015	Salesforce Inc	52.06	65.51	4.58
2014	Altaba Inc	47.32	66.68	3.83	2015	Baidu Inc	51.23	68.27	4.77
2014	Salesforce Inc	37.42	69.00	3.96	2015	Adobe Inc	46.76	70.79	4.95
2014	Adobe Inc	36.17	71.25	4.09	2015	Altaba Inc	31.56	72.49	5.07
2014	Intuit Inc.	26.32	72.89	4.18	2015	Activision Blizzard Inc	28.43	74.02	5.18
2014	Cerner Corp	22.08	74.26	4.26	2015	Intuit Inc.	25.48	75.39	5.27

Table A.2 – continues in the next page

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		Market cap.	Cumulative market share relative to				Market Cap	Cumulative market share relative to	
Year	Name	(billions)	Softw. market cap.	Total market cap.	Year	Name	(billions)	Softw. market cap.	Total market cap.
2016	Alphabet Inc	503.07	27.52	1.75	2017	Alphabet Inc	679.96	26.86	1.99
2016	Microsoft Corp	480.34	53.80	3.42	2017	Microsoft Corp	659.09	52.89	3.92
2016	Oracle Corp	157.74	62.43	3.97	2017	Oracle Corp	195.72	60.62	4.49
2016	Alibaba Group Holding Ltd	115.07	68.28	4.38	2017	Adobe Inc	86.09	64.02	4.74
2016	Adobe Inc	50.88	71.06	4.56	2017	Salesforce Inc	73.84	66.94	4.96
2016	Salesforce Inc	46.49	73.60	4.72	2017	Baidu Inc	65.75	69.54	5.15
2016	Baidu Inc	45.24	76.08	4.88	2017	Altaba Inc	48.22	71.66	5.31
2016	Altaba Inc	36.94	78.10	5.01	2017	Activision Blizzard Inc	47.97	73.55	5.45
2016	Intuit Inc.	29.42	79.71	5.11	2017	Intuit Inc.	40.34	75.15	5.57
2016	Activision Blizzard Inc	26.92	81.18	5.20	2017	Electronic Arts Inc	32.25	76.42	5.66
2018	Microsoft Corp	780.36	28.83	2.52	2019	Microsoft Corp	1200.25	31.50	3.06
2018	Alphabet Inc	674.83	53.76	4.69	2019	Alphabet Inc	858.94	54.05	5.25
2018	Oracle Corp	162.04	59.74	5.21	2019	Oracle Corp	169.94	58.51	5.69
2018	Adobe Inc	110.33	63.82	5.57	2019	Adobe Inc	159.08	62.68	6.09
2018	Salesforce Inc	104.78	67.69	5.91	2019	Salesforce Inc	144.26	66.47	6.46
2018	Intuit Inc.	51.08	69.58	6.07	2019	Intuit Inc.	68.18	68.26	6.64
2018	Baidu Inc	44.20	71.21	6.21	2019	ServiceNow Inc	53.25	69.65	6.77
2018	Activision Blizzard Inc	35.55	72.52	6.33	2019	Activision Blizzard Inc	45.68	70.85	6.89
2018	ServiceNow Inc	31.92	73.70	6.43	2019	Shopify Inc	41.21	71.93	6.99
2018	Roper Technologies Inc	28.29	74.73	6.51	2019	Autodesk Inc	40.29	72.99	7.10

Table A.2 – continues in the next page

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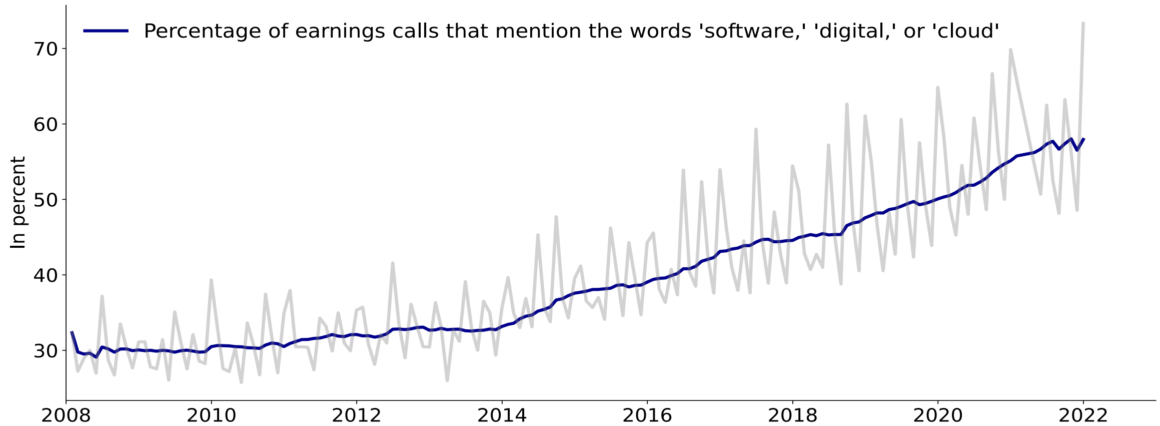
		Market cap.	Cumulative market share relative to				Market Cap	Cumulative market share relative to	
Year	Name	(billions)	Softw. market cap.	Total market cap.	Year	Name	(billions)	Softw. market cap.	Total market cap.
2020	Microsoft Corp	1678.38	28.00	3.54	2021	Microsoft Corp	2525.08	30.92	4.28
2020	Alphabet Inc	1102.83	46.40	5.87	2021	Alphabet Inc	1787.70	52.81	7.31
2020	Adobe Inc	239.56	50.39	6.38	2021	Adobe Inc	269.35	56.11	7.77
2020	Salesforce Inc	203.61	53.79	6.81	2021	Salesforce Inc	250.32	59.18	8.19
2020	Oracle Corp	190.45	56.97	7.21	2021	Oracle Corp	232.89	62.03	8.59
2020	Shopify Inc	124.56	59.04	7.47	2021	Intuit Inc.	182.14	64.26	8.90
2020	ServiceNow Inc	107.39	60.84	7.70	2021	Shopify Inc	156.52	66.17	9.16
2020	Intuit Inc.	99.80	62.50	7.91	2021	ServiceNow Inc	129.17	67.76	9.38
2020	Block Inc	83.53	63.89	8.08	2021	Snowflake Inc	103.76	69.03	9.56
2020	Activision Blizzard Inc	71.89	65.09	8.24	2021	Snap Inc	63.75	69.81	9.66
2022	Microsoft Corp	1785.94	35.88	3.89	2023	Microsoft Corp	2794.83	39.51	5.01
2022	Alphabet Inc	1055.04	57.08	6.19	2023	Alphabet Inc	1626.06	62.50	7.93
2022	Oracle Corp	220.39	61.51	6.68	2023	Adobe Inc	271.45	66.33	8.41
2022	Adobe Inc	155.48	64.63	7.01	2023	Oracle Corp	255.73	70.65	8.93
2022	Salesforce Inc	132.59	67.29	7.30	2023	Salesforce Inc	254.72	74.25	9.39
2022	Shopify Inc	109.57	68.78	7.50	2023	Intuit Inc.	174.97	76.72	9.70
2022	Intuit Inc.	109.34	70.98	7.74	2023	ServiceNow Inc	144.83	78.77	9.96
2022	ServiceNow Inc	78.59	72.56	7.91	2023	Synopsys Inc	78.26	79.87	10.10
2022	Activision Blizzard Inc	60.03	73.77	8.04	2023	Cadence Design Systems Inc	74.00	80.92	10.24
2022	VMware Inc	52.23	74.81	8.16	2023	Activision Blizzard Inc	73.67	82.10	10.38

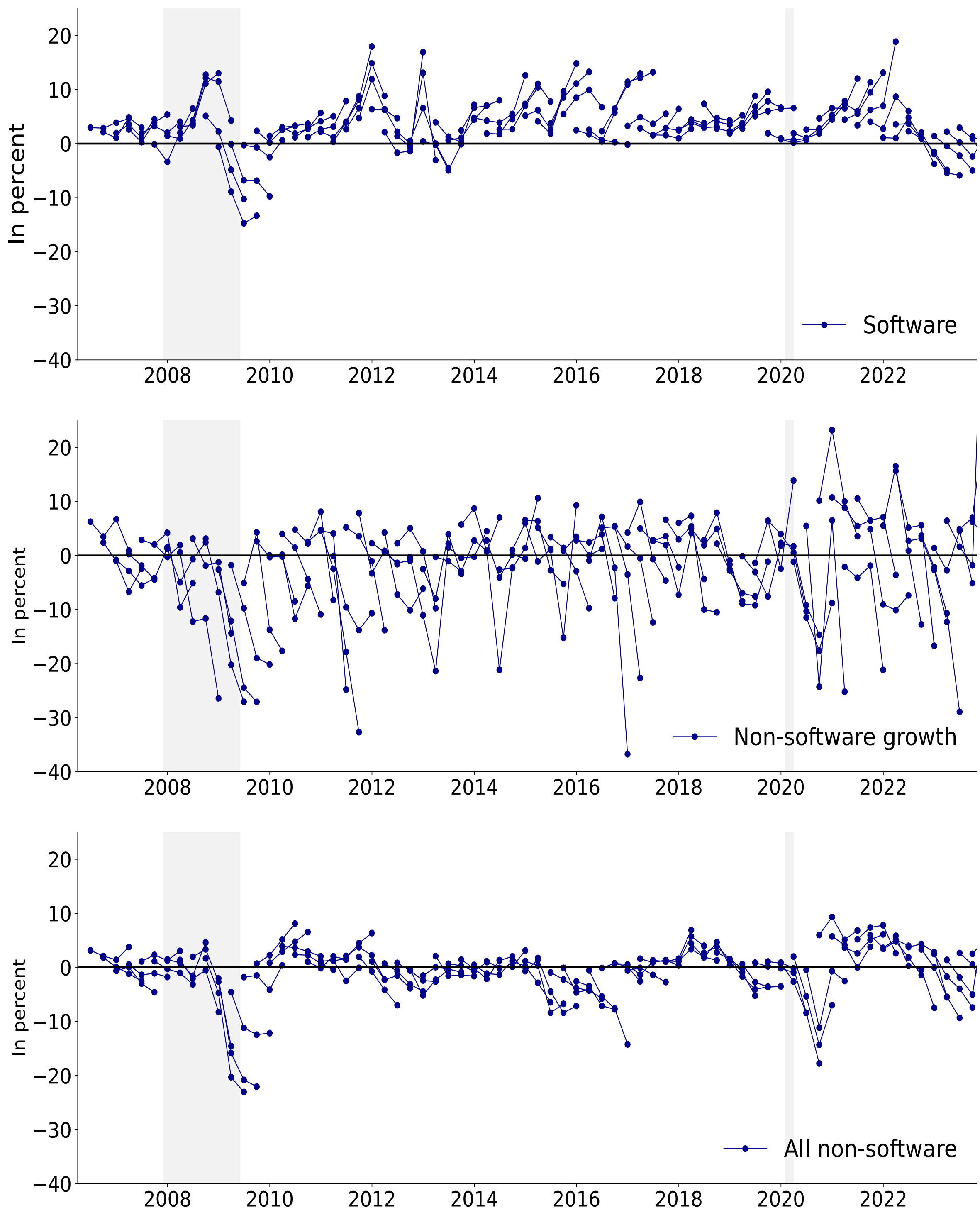
Notes: This table lists the ten largest software companies by market capitalization for each year from 1996 to 2023 as well as the cumulative market share relative to the market capitalization of all software companies and relative to the total market capitalization.

Fig. A.1. **Software Mentions in Earnings Calls**



Notes: This figure shows the percentage of earnings calls that mention at least one of the following words: *software*, *digital*, or *cloud*. We present average values at both quarterly (gray line) and yearly (blue line) frequencies. The figure spans the period from January 2008 through February 2022.

Fig. A.2. **Biases in Analysts' Forecasts: Post 2006**



Notes: This figure shows the average forecast bias for every quarter in our sample for software companies, non-software growth companies, and all non-software companies. Each line in the figure represents the average forecast error across the current quarter and the subsequent three quarters, while NBER recession dates are indicated by gray shaded bars. The sample spans from 2006Q1 to 2023Q3.

Table A.3. **Summary Statistics: Biases in Analysts' Forecasts**

A: Software companies

	Forecast horizon in quarters			
	1	2	3	4
Mean	2.21	1.78	2.21	2.94
t-statistic	[6.88]	[2.69]	[2.16]	[2.06]
std	20.51	39.33	55.27	73.10
5%	-8.59	-20.90	-31.19	-38.79
25%	-0.25	-3.23	-5.91	-7.84
50%	1.78	1.45	0.93	0.60
75%	4.65	6.15	7.43	8.78
95%	13.06	20.90	28.26	37.53
Observations	13,417	12,893	12,243	11,604 1

B: All non-software companies

	Forecast horizon in quarters			
	1	2	3	4
Mean	1.54	0.03	-1.41	-2.25
t-statistic	[7.15]	[0.08]	[-2.36]	[-2.98]
std	35.69	62.30	92.90	119.26
5%	-15.07	-27.37	-36.90	-43.39
25%	-2.15	-5.06	-7.42	-9.34
50%	0.81	0.25	-0.22	-0.55
75%	4.34	5.63	6.81	8.01
95%	18.78	27.15	35.71	43.48
Observations	212,216	202,813	189,954	178,155

C: Non-software growth companies

	Forecast horizon in quarters			
	1	2	3	4
Mean	2.41	-0.24	-4.64	-8.09
t-statistic	[6.07]	[-0.29]	[-3.71]	[-4.54]
std	45.08	86.90	130.82	169.30
5%	-16.62	-35.00	-53.45	-66.53
25%	-1.62	-4.97	-7.98	-10.55
50%	1.08	0.50	-0.07	-0.56
75%	4.55	5.93	6.98	7.83
95%	20.61	30.87	40.40	46.81
Observations	26,329	25,375	23,994	22,637

Notes: This table presents summary statistics of forecast errors for software companies, all non-software companies, and non-software growth companies. The sample spans from 1996Q1 to 2023Q3.

Table A.4. **Biases in Analysts' Forecasts: Robustness to the Measure of Consensus**

		Forecast horizon in quarters			
Coef	Variable	1	2	3	4
A: Using the median forecast as the measure of consensus					
a	1	2.21	1.78	2.21	2.94
t-statistic		[6.88]	[2.69]	[2.16]	[2.06]
Observations		13,417	12,893	12,243	11,604
B: Using the mean forecast as the measure of consensus					
a	1	2.02	1.50	2.07	2.77
t-statistic		[5.84]	[2.14]	[2.03]	[1.95]
Observations		13,418	12,894	12,243	11,604

Notes: This table presents the average forecast error for software companies using either the median forecast among analysts as the measure of consensus (Panel A) or the mean forecast (Panel B). The t-statistics, calculated using standard errors clustered by both firm and year-quarter, are included in square brackets. All forecast errors are presented as percentages. The sample spans from 1996Q1 to 2023Q3.

Table A.5. **Biases in Analysts' Forecasts: Subsample Analysis**

Sample of software companies		Forecast horizon in quarters			
Coef	Variable	1	2	3	4
A: Full sample period: 1996 to 2023					
a	1	2.21	1.78	2.21	2.94
t-statistic		[6.88]	[2.69]	[2.16]	[2.06]
Observations		13,417	12,893	12,243	11,60
B: Sample period: 1996 to 2005					
a	1	0.28	-2.26	-3.05	-5.13
t-statistic		[0.27]	[-1.18]	[-0.98]	[-1.20]
Observations		2,871	2,750	2,630	2,462
C: Sample period: 2006 to 2015					
a	1	2.51	2.79	3.79	5.41
t-statistic		[6.56]	[3.00]	[2.65]	[2.80]
Observations		5,021	4,918	4,751	4,605
D: Sample period: 2016 to 2023					
a	1	2.94	2.96	3.51	4.82
t-statistic		[8.80]	[4.07]	[3.04]	[2.82]
Observations		5,525	5,225	4,862	4,537

Notes: This table presents the average forecast error for software companies across various subperiods. Panel A details results for the entire 28-year span from 1996 to 2023. Panels B, C, and D focus on the intervals 1996-2005, 2006-2015, and 2016-2023, respectively. We include t-statistics in square brackets, calculated using standard errors that are clustered by both firm and year-quarter. All forecast errors are presented as percentages.

Table A.6. **Biases in Analysts' Forecasts: Robustness No Winsorization**

Sample of software companies					
		Forecast horizon in quarters			
Coef	Variable	1	2	3	4
A: Sample period: 1996 to 2023					
a	1	3.33	2.34	4.63	6.42
t-statistic		[3.03]	[2.49]	[2.70]	[2.05]
Observations		13,421	12,898	12,249	11,608
B: Sample period: 1996 to 2005					
a	1	5.40	0.82	5.65	6.07
t-statistic		[1.07]	[0.26]	[0.86]	[0.48]
Observations		2,873	2,752	2,634	2,463
C: Sample period: 2006 to 2023					
a	1	2.76	2.75	4.34	6.51
t-statistic		[10.14]	[3.41]	[3.54]	[3.19]
Observations		10,548	10,146	9,615	9,145

Notes: This table presents the average forecast error for software companies when we do not winsorize outliers. We present results across various subperiods. Panel A details results for the entire 28-year span from 1996 to 2023. Panels B and C focus on the intervals 1996-2005, 2006-2023, respectively. We include t-statistics in square brackets, calculated using standard errors that are clustered by both firm and year-quarter. All forecast errors are presented as percentages.

Table A.7. **Biases in Analysts' Forecasts: Robustness Winsorize Outliers at the 99% Level in Absolute Value**

Sample of software companies					
		Forecast horizon in quarters			
Coef	Variable	1	2	3	4
A: Sample period: 1996 to 2023					
a	1	2.07	1.28	0.61	0.49
t-statistic		[8.95]	[2.71]	[0.89]	[0.52]
Observations		13,384	12,855	12,198	11,546
B: Sample period: 1996 to 2005					
a	1	1.16	-1.21	-2.72	-4.90
t-statistic		[1.60]	[-0.84]	[-1.18]	[-1.50]
Observations		2,863	2,738	2,616	2,442
C: Sample period: 2006 to 2023					
a	1	2.32	1.95	1.52	1.93
t-statistic		[11.59]	[4.84]	[2.68]	[2.57]
Observations		10,521	10,117	9,582	9,104

Notes: This table presents the average forecast error for software companies when we winsorize outliers by removing forecast errors that exceed the 99th percentile in absolute value for each forecast horizon. We present results across various subperiods. Panel A details results for the entire 28-year span from 1996 to 2023. Panels B and C focus on the intervals 1996-2005, 2006-2023, respectively. We include t-statistics in square brackets, calculated using standard errors that are clustered by both firm and year-quarter. All forecast errors are presented as percentages.

Table A.8. **Biases in Analysts' Forecasts: Robustness to Market Cap**

	I	II		III	
	Software	All non-software	I - II	Non-software growth	I - III
	(1)	(2)	(3)	(4)	(5)
Forecast horizon: 1 quarter					
Average bias	2.25	1.46	0.79	1.80	0.45
t-statistic	[8.99]	[6.81]	[2.96]	[4.72]	[1.15]
Observations	13,143	178,714	191,857	22,861	36,004
Forecast horizon: 2 quarters					
Average bias	1.66	-0.18	1.84	-0.80	2.46
t-statistic	[2.80]	[-0.38]	[2.91]	[-0.90]	[2.64]
Observations	12,174	162,505	174,679	20,958	33,132
Forecast horizon: 3 quarters					
Average bias	1.92	-1.72	3.64	-4.85	6.76
t-statistic	[2.13]	[-2.91]	[3.97]	[-4.05]	[4.85]
Observations	11,018	142,100	153,118	18,456	29,474
Forecast horizon: 4 quarters					
Average bias	3.11	-2.05	5.16	-7.86	10.98
t-statistic	[2.63]	[-2.83]	[4.25]	[-4.85]	[5.76]
Observations	10,143	124,764	134,907	16,185	26,328

Notes: This table presents the average forecast error for companies that have more than two analysts following the firm. Columns 1, 2, and 4 present regression results for the equation: $e^{(k)}_{t+h|t} = a_h + u^{(k)}_{t+h}$, where $e^{(k)}_{t+h|t}$ is the forecast error for company k at horizon h, a_h is the average bias at horizon h, and $u^{(k)}_{t+h}$ is the error term. The regressions are run separately for the set of software companies, all non-software companies, and non-software growth firms. In columns 3 and 5, we estimate the following regression: $e^{(k)}_{t+h|t} = a + b \cdot 1^{(k)}_{t,sw} + u^{(k)}_{t+h}$, where $1^{(k)}_{t,sw}$ is an indicator variable set to one if company k is classified as a software company in period t, and zero otherwise. The coefficient b represents the difference in average bias between software companies and the comparison group. Column 3 uses all non-software companies as the comparison group, while column 5 uses only non-software growth firms. The t-statistics, calculated using standard errors clustered by both firm and date, are reported in square brackets. The forecast errors are expressed in percent. The sample spans from 1996Q1 to 2023Q3.

Table A.9. **Biases in Individual Analysts' Forecasts**

Subsample of analysts covering software companies					
		Forecast horizon in quarters			
Coef	Variable	1	2	3	4
a	1	1.38	0.39	-0.09	-0.04
t-statistic		[8.36]	[0.98]	[-0.16]	[-0.06]
b	$\mathbb{1}_{t,sw}^{(k)}$	1.32	2.13	2.88	3.22
t-statistic		[7.20]	[5.51]	[4.94]	[4.52]
Observations		460,393	344,219	279,823	231,981

Notes: This table presents regression results for the equation: $e_{t+h|t}^{(k,i)} = a + b \cdot \mathbb{1}_{t,sw}^{(k)} + u_{t+h}^{(k,i)}$, using only the sample of analysts who issue forecasts for software companies. The variable $\mathbb{1}_{t,sw}^{(k)}$ is an indicator variable set to one if company k is classified as a software company in period t and zero otherwise. $e_{t+h|t}^{(k,i)}$ denotes the forecast error of analyst i for firm k. The t-statistics, based on standard errors clustered by both analyst and year-quarter, are reported in square brackets. The forecast error is expressed in percent, and the sample spans from 1996Q1 to 2023Q3.

Table A.10. **Biases in Analysts' Forecasts: Other Industries**

Coef	Variable	Forecast horizon in quarters 1	2	3	4
A: Prepackaged software (7372)					
a	1	1.76	0.51	0.70	2.34
t-statistic		[2.82]	[0.35]	[0.39]	[1.10]
Observations		5,677	3,958	3,164	2,573
B: Computer programming, data processing (7370)					
a	1	1.53	1.02	0.67	0.62
t-statistic		[4.64]	[1.58]	[0.75]	[0.60]
Observations		29,267	22,321	17,970	14,356
C: Semiconductors and related devices (3674)					
a	1	1.68	0.64	-0.35	-0.68
t-statistic		[5.09]	[0.62]	[-0.25]	[-0.40]
Observations		19,989	16,183	14,273	12,560
D: Computer integrated systems design (7373)					
a	1	1.01	-0.14	-0.55	-0.26
t-statistic		[3.49]	[-0.21]	[-0.51]	[-0.18]
Observations		5,304	3,797	3,199	2,784
E: Data processing and preparation (7374)					
a	1	1.19	1.10	1.27	2.29
t-statistic		[1.69]	[1.26]	[1.16]	[1.71]
Observations		9,523	7,379	6,125	5,163
F: Computer facilities management (3576)					
a	1	1.31	1.04	0.82	0.72
t-statistic		[3.98]	[1.47]	[0.74]	[0.49]
Observations		9,633	7,668	6,711	5,975

Notes: This table presents the average forecast error for individual analysts covering non-software companies in industries related to the software sector. We identify these industries by examining the coverage of analysts who issue forecasts for both software and non-software companies. The top 6 industries are selected based on the frequency of such overlapping coverage. Panels A to F report the average forecast errors for non-software companies within the Prepackaged Software industry (SIC code 7372), Computer Programming and Data Processing (7370), Semiconductors and Related Devices (3674), Computer Integrated Systems Design (7373), Data Processing and Preparation (7374), and Computer Facilities Management (3576). For each industry, we provide the corresponding SIC code in parentheses. The t-statistics, calculated using standard errors clustered by both firm and year-quarter, are reported in square brackets. All forecast errors are expressed as percentages.

Table A.11. **Learning within a Specific Forecaster**

Coef	Variable	Forecast horizon in quarters 1	2	3	4
a	1	3.05	3.11	3.85	4.06
t-statistic		[11.96]	[6.12]	[4.57]	[3.82]
b	$\mathbb{1}^{(k,i)}_{t,Medium}$	-0.40	-0.48	-0.90	-0.40
t-statistic		[-2.07]	[-1.59]	[-1.63]	[-0.63]
c	$\mathbb{1}^{(k,i)}_{t,High}$	-0.90	-1.63	-2.85	-2.69
t-statistic		[-3.26]	[-4.02]	[-4.22]	[-3.35]
Observations		105,641	76,775	62,492	53,162

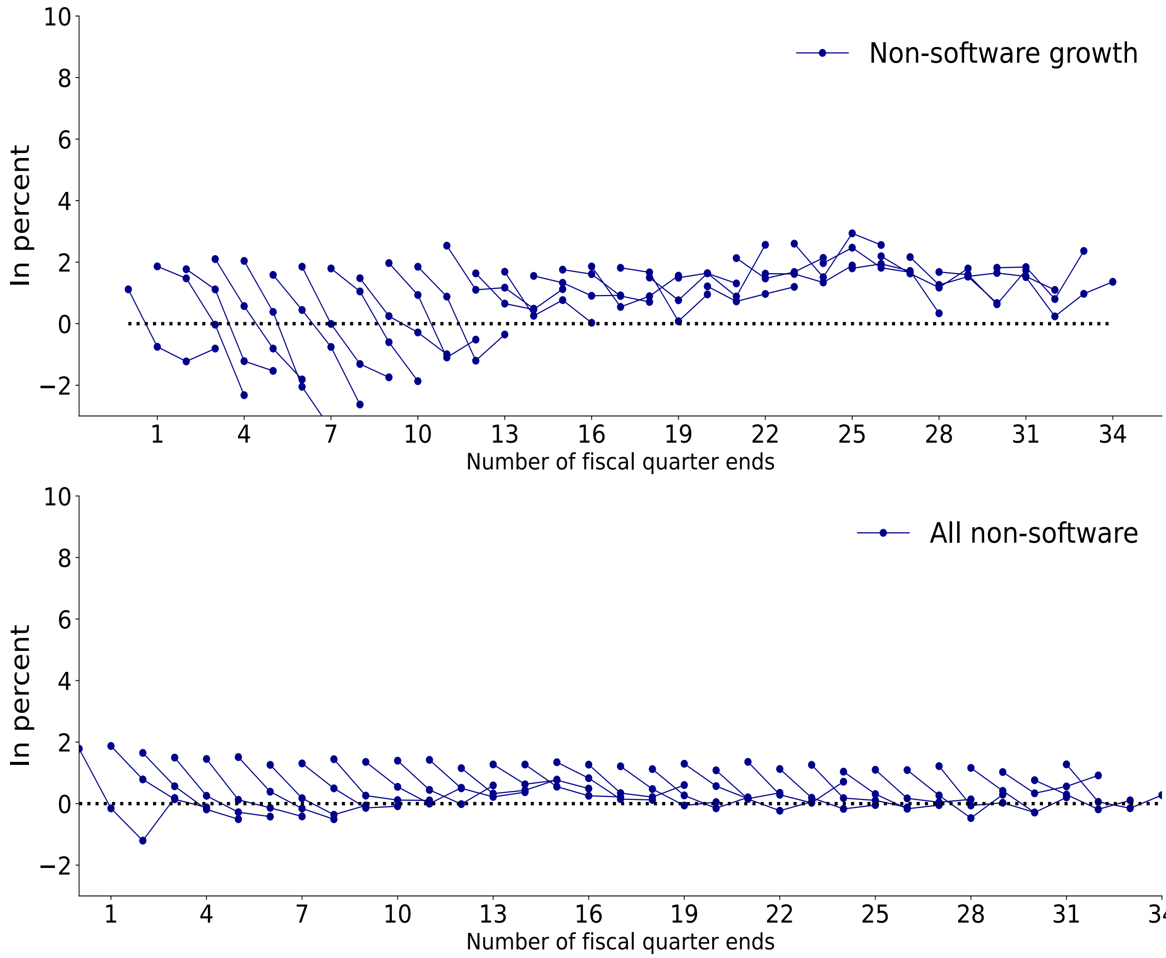
Notes: This table presents regression results for the equation: $e^{(k,i)}_{t+h|t} = a + b \cdot \mathbb{1}^{(k,i)}_{t,Medium} + c \cdot \mathbb{1}^{(k,i)}_{t,High} + u^{(k,i)}_{t+h}$, where $\mathbb{1}^{(k,i)}_{t,Medium}$ and $\mathbb{1}^{(k,i)}_{t,High}$ are indicator variables taking a value of 1 if analyst i has issued a medium or high number of forecasts, respectively, about software company k. The medium and high thresholds are based on the middle and top terciles of the distribution of the number of forecasts made by all analysts. t-statistics, based on standard errors clustered by both analyst and year-quarter, are reported in square brackets. Forecast errors are expressed in percent, and the sample spans from 1996Q1 to 2023Q3.

Table A.12. **Learning within the Consensus Forecast**

Coef	Variable	Forecast horizon in quarters 1	2	3	4
a	1	2.92	3.17	4.42	5.13
t-statistic		[4.68]	[2.16]	[1.68]	[1.34]
b	$\mathbb{1}^{(k)}_{t,Medium}$	-0.94	-1.54	-2.42	-1.76
t-statistic		[-1.16]	[-0.93]	[-0.88]	[-0.44]
c	$\mathbb{1}^{(k)}_{t,High}$	-1.13	-2.49	-3.95	-4.44
t-statistic		[-1.64]	[-1.61]	[-1.47]	[-1.15]
Observations		13,418	12,894	12,244	11,605

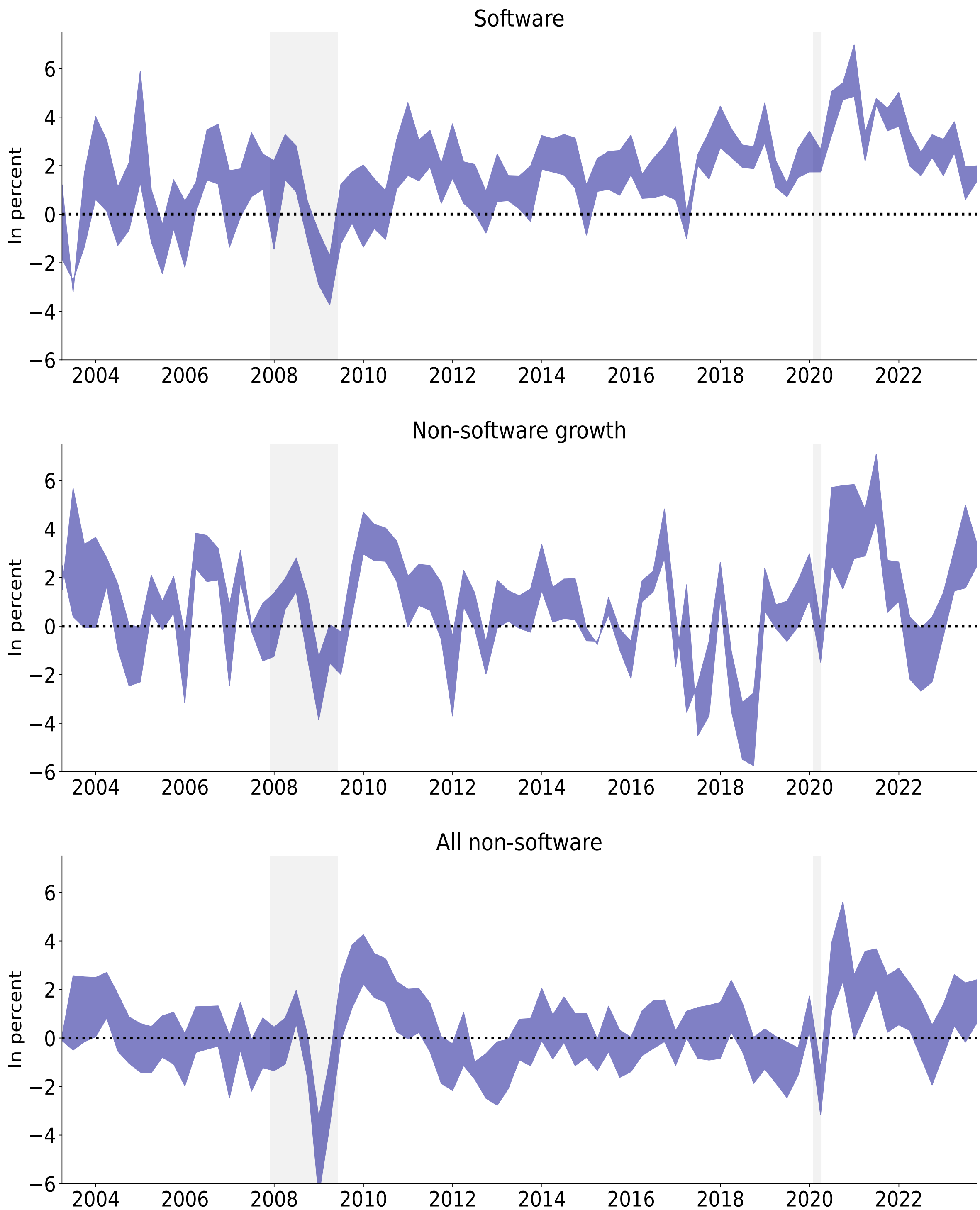
Notes: This table presents regression results for the equation: $e^{(k)}_{t+h|t} = a + b \cdot \mathbb{1}^{(k)}_{t,Medium} + c \cdot \mathbb{1}^{(k)}_{t,High} + u^{(k)}_{t+h}$, where $\mathbb{1}^{(k)}_{t,Medium}$ and $\mathbb{1}^{(k)}_{t,High}$ are indicator variables taking a value of 1 if the analysts' consensus has issued a medium or high number of forecasts, respectively, about software company k. The medium and high thresholds are based on the middle and top terciles of the distribution of the number of forecasts made for each company k at each time period t. t-statistics, based on standard errors clustered by both analyst and year-quarter, are reported in square brackets. Forecast errors are expressed in percent, and the sample spans from 1996Q1 to 2023Q3.

Fig. A.3. **Learning within a Specific Forecaster**



Notes: This figure shows the average forecast error for non-software growth companies (upper panel) and all non-software companies (lower panel) based on the number of prior forecasts an analyst i has issued for company k before time t. Each line represents the average forecast error for the current quarter and the subsequent three quarters. The sample covers the period from 1996 to 2023.

Fig. A.4. **Biases in Firm Forecasts**



Notes: This figure reports the mean forecast errors associated with one-quarter-ahead management guidance values for software and non-software firms, in percentages. The bands represent the range of forecasts provided by management. The gray shaded bars represent NBER recession dates. The figure spans from 2003 to 2023.

Table A.13. **Performance Evaluation and Alphas: Subsample Analysis**

A: Equally-weighted returns	Software *minus* all non-software			Software *minus* non-software growth		
	1996 - 2023 (1)	1996 - 2005 (2)	2006 - 2023 (3)	1996 - 2023 (4)	1996 - 2005 (5)	2006 - 2023 (6)
Average return spread	7.61	11.30	5.56	11.48	19.78	6.88
t-statistic	[2.12]	[1.27]	[2.06]	[4.05]	[3.62]	[3.84]
Three-factor alpha	6.16	12.20	4.21	11.30	17.37	7.52
t-statistic	[2.38]	[1.85]	[2.80]	[4.64]	[3.10]	[4.57]
Four-factor alpha	6.12	13.37	4.01	10.59	15.99	7.36
t-statistic	[2.48]	[2.15]	[2.52]	[4.78]	[3.08]	[4.38]

B: Value-weighted returns	Software *minus* all non-software			Software *minus* non-software growth		
	1996 - 2023 (1)	1996 - 2005 (2)	2006 - 2023 (3)	1996 - 2023 (4)	1996 - 2005 (5)	2006 - 2023 (6)
Average return spread	5.71	5.57	5.79	4.71	8.17	2.78
t-statistic	[2.11]	[0.90]	[2.59]	[2.49]	[1.93]	[1.56]
Three-factor alpha	4.85	12.65	3.99	3.46	10.63	2.40
t-statistic	[2.37]	[2.50]	[2.18]	[1.78]	[2.31]	[1.22]
Four-factor alpha	4.75	12.59	3.91	3.35	10.85	2.29
t-statistic	[2.28]	[2.14]	[2.09]	[1.66]	[1.99]	[1.13]

Notes: This table presents performance evaluation measures and factor alphas for long-short portfolios, with Panel A focusing on equally-weighted portfolios and Panel B on value-weighted portfolios. In both panels, Columns 1 to 3 show results for the portfolio that buys software companies and sells all non-software companies, while Columns 4 to 6 present results for the portfolio that buys software companies and sells non-software growth companies. All returns are annualized and expressed as a percentage per year by multiplying monthly returns by 1,200. The t-statistics are reported in brackets. The sample period spans from January 1996 through December 2023.

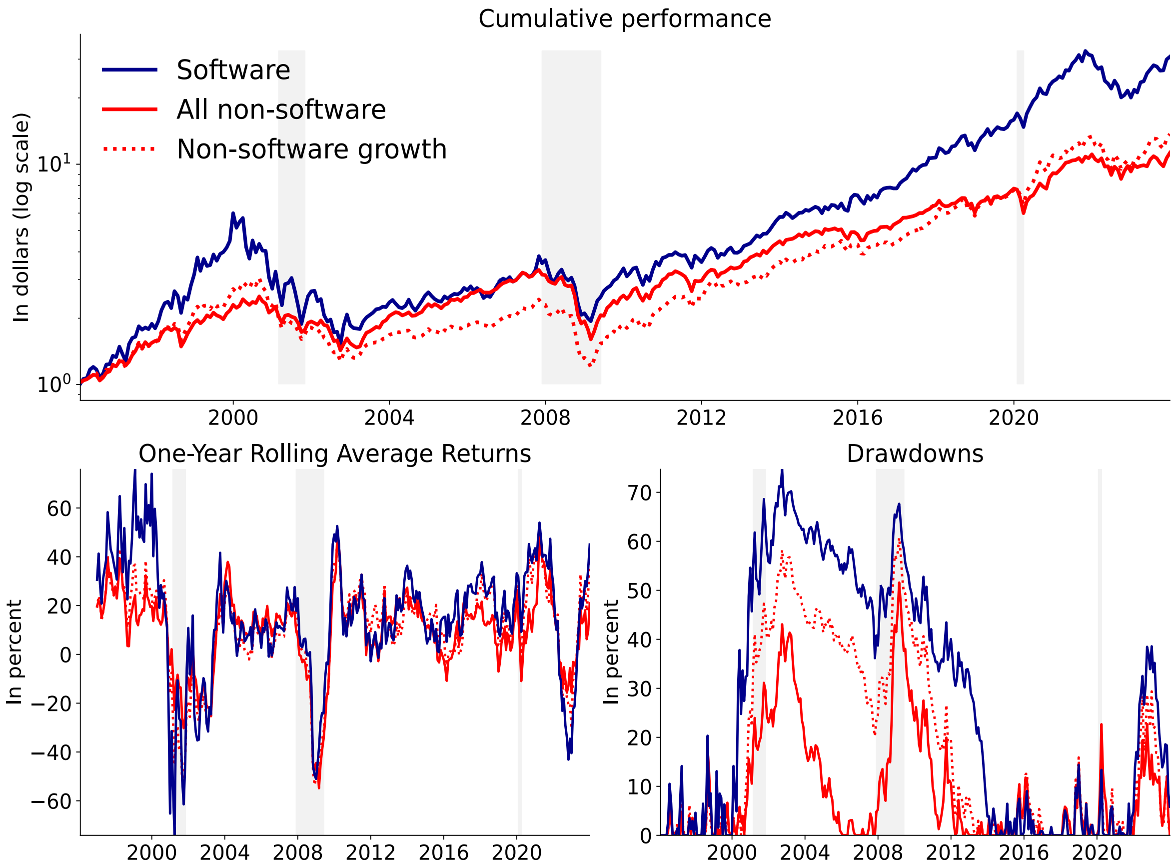
Table A.14. **Performance Evaluation and Alphas: Controlling for microcap stocks**

A: Equally-weighted returns using non-microcaps	Software *minus* all non-software			Software *minus* non-software growth		
	1996 - 2023	1996 - 2005	2006 - 2023	1996 - 2023	1996 - 2005	2006 - 2023
	(1)	(2)	(3)	(4)	(5)	(6)
Average return spread	7.13	7.93	6.68	7.21	11.98	4.57
t-statistic	[1.87]	[0.82]	[2.37]	[2.66]	[1.89]	[2.28]
Three-factor alpha	5.23	10.05	4.77	6.53	10.90	4.67
t-statistic	[0.92]	[1.46]	[3.05]	[2.78]	[1.75]	[2.93]
Four-factor alpha	4.83	10.31	4.45	5.63	8.98	4.44
t-statistic	[2.16]	[1.74]	[2.66]	[3.02]	[1.76]	[2.62]

B: Equally-weighted returns using microcaps	Software *minus* all non-software			Software *minus* non-software growth		
	1996 - 2023	1996 - 2005	2006 - 2023	1996 - 2023	1996 - 2005	2006 - 2023
	(1)	(2)	(3)	(4)	(5)	(6)
Average return spread	9.05	17.17	4.54	17.78	29.01	11.54
t-statistic	[2.38]	[2.05]	[1.65]	[5.11]	[4.76]	[6.15]
Three-factor alpha	8.40	17.06	4.30	18.37	25.01	12.98
t-statistic	[2.54]	[2.15]	[2.01]	[5.83]	[4.04]	[6.00]
Four-factor alpha	9.07	20.74	4.17	18.01	25.32	12.81
t-statistic	[2.39]	[2.41]	[1.99]	[5.56]	[3.88]	[6.09]

Notes: This table presents performance evaluation measures and factor alphas for long-short portfolios, with Panel A focusing on equally-weighted portfolios using non-microcap stocks and Panel B on equally-weighted portfolios using microcap stocks. Microcap stocks are those smaller than the 20th percentile of the market equity for NYSE stocks. In both panels, Columns 1 to 3 show results for the portfolio that buys software companies and sells all non-software companies, while Columns 4 to 6 present results for the portfolio that buys software companies and sells non-software growth companies. All returns are annualized and expressed as a percentage per year by multiplying monthly returns by 1,200. The t-statistics are reported in brackets. The sample period spans from January 1996 through December 2023.

Fig. A.5. **Cumulative Returns on Value-weighted Portfolios**



Notes: The top panel plots the cumulative returns to a value weighted portfolio of software companies, non-software companies, and non-software growth companies from January 1996 to December 2023. The y-axis is on a log scale and all portfolios start with a \$1 investment in 1996, assuming no transaction costs. The lower left panel plots rolling one-year returns for each portfolio, and the lower right panel shows the drawdown of each portfolio, which measures the maximum loss from a peak to a trough before a new peak is attained.

Table A.15. **Performance Evaluation and Alphas: Value firms**

	Software value *minus* non-software value		
	1996 - 2023 (1)	1996 - 2005 (2)	2006 - 2023 (3)
Average return spread	8.01	12.82	5.34
t-statistic	[1.90]	[1.27]	[1.51]
Three-factor alpha	7.85	11.98	5.14
t-statistic	[2.20]	[1.27]	[2.18]
Four-factor alpha	7.72	11.35	5.23
t-statistic	[2.76]	[1.42]	[2.28]

Notes: This table presents performance evaluation measures and factor alphas for long-short value-weighted portfolios. Columns 1 to 3 show results for the portfolio that buys software value companies and sells non-software value companies. We classify a company as value if it belongs to the highest five deciles of portfolios sorted on Book-to-Market ratio. Returns are annualized and expressed in percent per year by multiplying monthly returns by 1,200. The t-statistics are reported in brackets. The sample spans from January 1996 through December 2023.

Table A.16. **Performance Evaluation and Alphas: Value-minus-growth returns**

A: Sample of software companies			
	Value *minus* growth		
	1996 - 2023 (1)	1996 - 2005 (2)	2006 - 2023 (3)
Average return spread	2.12	11.56	-3.13
t-statistic	[0.39]	[0.91]	[-0.93]
Three-factor alpha	2.54	-0.18	-0.55
t-statistic	[0.64]	[-0.02]	[-0.18]
Four-factor alpha	2.15	-2.48	-0.25
t-statistic	[0.66]	[-0.26]	[-0.08]
B: Sample of non-software companies			
	Value *minus* growth		
	1996 - 2023 (1)	1996 - 2005 (2)	2006 - 2023 (3)
Average return spread	-0.70	5.84	-4.33
t-statistic	[-0.23]	[0.99]	[-1.57]
Three-factor alpha	-1.83	-3.24	-2.49
t-statistic	[-1.81]	[-1.99]	[-2.41]
Four-factor alpha	-1.82	-2.92	-2.48
t-statistic	[-1.87]	[-1.62]	[-2.40]

Notes: This table presents performance evaluation measures and factor alphas for value-growth value-weighted portfolios. Panel A reports results for the sample of software companies, while Panel B reports results for the sample of non-software companies. All returns are annualized and expressed as a percentage per year by multiplying monthly returns by 1,200. The *t*-statistics are reported in brackets. The sample period spans from January 1996 through December 2023.

Table A.17. **Coibion-Gorodnichenko Regressions using Long-Term Forecasts**

	Software Forecast horizon in years				Non-software Forecast horizon in years			
	1	2	3	4	1	2	3	4
Data consensus	0.09	0.16	0.27	–	0.05	0.03	0.21	–
t-statistic	[3.63]	[2.67]	[1.34]	–	[4.87]	[1.05]	[3.86]	–
Data individual	0.15	0.27	0.55	–	0.05	0.02	0.19	–
t-statistic	[5.51]	[2.69]	[1.88]	–	[2.08]	[0.57]	[2.47]	–

Notes: This table presents Coibion-Gorodnichenko regression coefficients for horizons of one, two, and three years. The t-statistics are presented in brackets, where standard errors are clustered by both firm and date. The forecast horizons are in years, and the forecast errors and forecast revisions used in the tests are expressed in percent. The sample spans from 1996 to 2023.

Appendix B Additional analyses

This section presents additional robustness tests and analyses. The subsections are self-contained, enabling readers to selectively navigate through them without loss.

B.1 Stock return predictability around revenue announcements

In this section, we examine the predictability of stock returns around revenue announcements. Specifically, we investigate the immediate price reactions in the minutes following quarterly revenue announcements, as well as the long-term price dynamics over the year following the same announcements.

Immediate stock price reaction. We use high-frequency data to show the differential price reaction to revenue announcements for software, all non-software and non-software growth companies in a narrow window around the time of revenue announcement. The high-frequency data comes from the New York Stock Exchange (2003–2023) Trade and Quote (TAQ) dataset, and we consider all stocks traded in the New York Stock Exchange, American Stock Exchange, and Nasdaq National Market System stock markets.

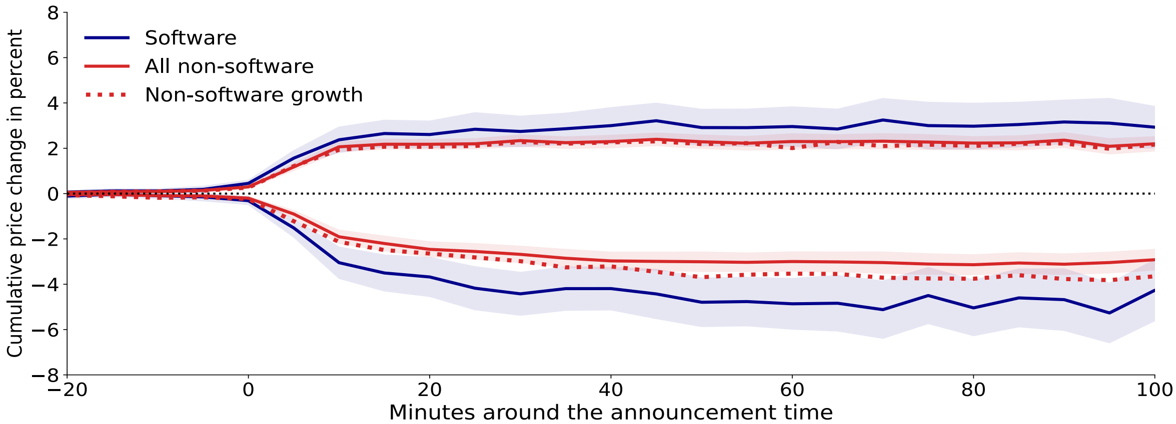
Each quarter, we sort firms into low, medium, and high tercile portfolios based on the news from the quarter-t revenue announcement. Figure B.1 displays the cumulative stock price response in the 20 minutes preceding and the 100 minutes following the revenue announcement for the low and high terciles. While the three sets of firms experience similar price reactions to positive news, software firms exhibit a larger negative price response to negative revenue news, followed by non-software growth and then all non-software companies. Specifically, these companies experience an immediate drop in prices, and the price reaction to bad news continues to trend downward in subsequent minutes, reaching approximately -4.26%, -3.65%, and -2.91% for software, non-software growth, and all non-software companies, respectively, 90 minutes post-announcement.

Long-term stock price dynamics. To explore the long-term price dynamics, we examine the daily returns in the year following the revenue announcement. Since we focus on longer time windows, we control for aggregate market movements by computing Fama-French three-factor adjusted returns (FF3 adjusted returns). For the daily returns we use the CRSP daly stock file (Center for Research in Security Prices, 1996–2023a).

We stratify firm observations into terciles based on the time-t revenue surprises and calculate mean FF3-adjusted realized returns for a total of four quarters following the time-t revenue announcement, where quarter 0 is defined as the quarter immediately following the announcement. Moreover, each quarter is defined as starting on the day of the $t + h$ revenue announcement and ending one day before the following revenue announcement date.

Panel A of Table B.1 presents the results, with standard errors clustered at both the firm and year-quarter levels. We first focus on the price reaction following low revenue surprises. Consistent with the high-frequency results in Figure B.1, we observe that in the quarter of the revenue announcement (i.e., quarter 0), the average quarterly abnormal return for software firms reporting low revenue surprises is -3.81% (column 1), while the corresponding returns for non-software firms and non-software growth firms are -2.83% (column 3) and -2.70% (column 5), respectively. However, over the four quarters following the announcement, the quarterly negative abnormal returns for software firms

Fig. B.1. **High-Frequency Stock Price Reaction to Revenue Announcements**



Notes: This figure shows the differential price reaction to revenue announcements for software (darkblue), non-software growth (dotted red line), and all non-software firms (red), in percentages. We sort firms into terciles based on revenue announcement news in quarter t. We show the average percent change in price in the 20 minutes before and the 100 minutes following firm revenue announcements with 99% confidence intervals. We obtain NYSE Trade and Quote (TAQ) intraday transaction data for all firms listed on the New York Stock Exchange, American Stock Exchange, and Nasdaq National Market System stock markets and measure the percent change in price over the noted window of time for the period spanning April 2003 through December 2022.

become positive and statistically significant, with mean quarterly abnormal returns of 1.84% (t-statistic = 2.03), 2.08% (t-statistic = 2.50), 1.28% (t-statistic = 1.54), and 2.46% (t-statistic = 2.60), respectively. In contrast, the mean quarterly abnormal returns for non-software firms and non-software growth firms are close to zero and statistically insignificant.

Columns 2, 4, and 6 of Panel A in Table B.1 present the results on the price reaction following high revenue surprises. Column 2 displays the quarterly mean abnormal returns for software companies with the highest revenue surprises. The mean abnormal return is positive and high for the first quarter, with a value of 4.27% (t-statistic = 6.53). In the subsequent four quarters, the average quarterly abnormal returns for software firms remain positive, with values ranging between 0.36% and 0.71%. On the other hand, columns 4 and 6 show that mean abnormal returns for non-software and non-software growth companies are positive only in the first quarter, with a value of about 2.5%, and close to zero and statistically insignificant for the subsequent quarters. Panel B of Table B.1 shows robustness results using Fama–French/Carhart's four-factor model-adjusted returns.

Table B.1. **Quarterly Abnormal Returns around Revenue Announcements**

A: Average three-factor adjusted returns	Software		All non-software		Non-software growth	
Quarter after announcement	Low (1)	High (2)	Low (3)	High (4)	Low (5)	High (6)
0 quarter	-3.81	4.27	-2.83	2.48	-2.70	2.48
t-statistic	[-4.23]	[6.53]	[-5.93]	[6.78]	[-5.33]	[6.39]
1 quarter	1.84	0.49	-0.18	-0.04	-0.11	-0.04
t-statistic	[2.03]	[0.91]	[-0.32]	[-0.14]	[-0.19]	[-0.12]
2 quarter	2.08	0.71	-0.09	0.00	0.00	0.06
t-statistic	[2.50]	[1.32]	[-0.17]	[0.01]	[0.00]	[0.24]
3 quarter	1.28	0.42	-0.08	-0.15	-0.03	-0.08
t-statistic	[1.54]	[0.72]	[-0.24]	[-0.58]	[-0.08]	[-0.27]
4 quarter	2.46	0.36	0.25	-0.17	0.31	-0.12
t-statistic	[2.60]	[0.75]	[0.52]	[-0.75]	[0.63]	[-0.52]
B: Average four-factor adjusted returns	Software		All non-software		Non-software growth	
Quarter after announcement	Low (1)	High (2)	Low (3)	High (4)	Low (5)	High (6)
0 quarter	-3.93	4.09	-3.03	2.34	-2.91	2.35
t-statistic	[-4.82]	[6.59]	[-9.52]	[7.87]	[-8.81]	[7.71]
1 quarter	1.62	0.31	-0.43	-0.14	-0.37	-0.11
t-statistic	[2.16]	[0.57]	[-1.31]	[-0.52]	[-1.09]	[-0.39]
2 quarter	1.75	0.62	-0.31	-0.09	-0.25	-0.01
t-statistic	[2.27]	[1.14]	[-0.96]	[-0.40]	[-0.72]	[-0.05]
3 quarter	1.10	0.22	-0.19	-0.27	-0.15	-0.20
t-statistic	[1.44]	[0.37]	[-0.78]	[-1.29]	[-0.61]	[-0.86]
4 quarter	2.23	0.25	0.07	-0.30	0.12	-0.25
t-statistic	[2.53]	[0.54]	[0.22]	[-1.65]	[0.37]	[-1.39]

Notes: This table presents realized quarterly abnormal returns for portfolios sorted based on revenue news for quarters $h = 0, 1, 2, 3, 4$, where quarter 0 is the quarter immediately following the revenue announcement. Firms are sorted into terciles based on revenue announcement news in quarter 0. Panel A reports results using the Fama-French three-factor (FF3) model, while Panel B shows robustness results using the Fama–French/Carhart four-factor (FF4) model. To compute abnormal returns, we use the FF3 or FF4 model with a rolling 252-daily estimation window (requiring a minimum of 126 days of data) to estimate factor betas. The realized return for each quarter is measured starting on the day of the $t + h$ revenue announcement and ending one day before the following revenue announcement date. The sample period spans from December 1996 through December 2023.

Panel A of Table B.2 presents the cumulative FF3 abnormal returns over the first four quarters following a revenue surprise. Column 1 shows that for software firms in the lowest tercile, initially negative returns are observed. However, returns reverse by the third quarter, resulting in a cumulative positive return. In contrast, non-software and non-software growth firms exhibit a much flatter price response in the quarters following the revenue announcement, with no evidence of reversals. Panel B of Table B.2 reports

Table B.2. **Cumulative Abnormal Returns around Revenue Announcements**

Panel A: Cumulative three-factor adjusted returns

	Software		All non-software		Non-software growth	
	Low	High	Low	High	Low	High
Cumulative period	(1)	(2)	(3)	(4)	(5)	(6)
0 quarter to 0 quarter	-3.81	4.27	-2.83	2.48	-2.70	2.48
t-statistic	[-4.23]	[6.53]	[-5.93]	[6.78]	[-5.33]	[6.39]
0 quarter to 1 quarter	-2.46	4.96	-2.73	2.50	-2.49	2.52
t-statistic	[-1.51]	[4.98]	[-3.08]	[5.78]	[-2.66]	[5.57]
0 quarter to 2 quarter	-0.15	5.64	-3.28	2.68	-3.06	2.77
t-statistic	[-0.05]	[4.34]	[-3.89]	[4.88]	[-3.47]	[4.89]
0 quarter to 3 quarter	1.90	5.99	-3.16	2.76	-2.88	2.88
t-statistic	[0.44]	[3.66]	[-3.33]	[4.47]	[-2.93]	[4.50]
0 quarter to 4 quarter	5.84	5.84	-2.74	2.67	-2.38	2.85
t-statistic	[0.95]	[3.11]	[-2.57]	[3.88]	[-2.15]	[4.05]

Panel B: Cumulative four-factor adjusted returns

	Software		All non-software		Non-software growth	
	Low	High	Low	High	Low	High
Cumulative period	(1)	(2)	(3)	(4)	(5)	(6)
0 quarter to 0 quarter	-3.93	4.09	-3.03	2.34	-2.91	2.35
t-statistic	[-4.82]	[6.59]	[-9.52]	[7.87]	[-8.81]	[7.71]
0 quarter to 1 quarter	-2.72	4.72	-3.30	2.34	-3.11	2.39
t-statistic	[-1.88]	[4.83]	[-7.11]	[6.05]	[-6.37]	[6.05]
0 quarter to 2 quarter	-0.56	5.29	-3.74	2.44	-3.56	2.59
t-statistic	[-0.22]	[4.13]	[-7.10]	[4.92]	[-6.50]	[5.13]
0 quarter to 3 quarter	1.28	5.40	-3.66	2.40	-3.44	2.58
t-statistic	[0.33]	[3.37]	[-5.80]	[4.25]	[-5.26]	[4.46]
0 quarter to 4 quarter	4.93	5.22	-3.28	2.21	-3.00	2.44
t-statistic	[0.91]	[2.86]	[-4.37]	[3.44]	[-3.83]	[3.75]

Notes: This table presents cumulative quarterly abnormal returns for portfolios sorted based on revenue news for quarters $h = 0, 1, 2, 3, 4$, where quarter 0 is the quarter immediately following the revenue announcement. Firms are sorted into terciles based on revenue announcement news in quarter 0. Panel A reports results using the Fama-French three-factor (FF3) model, while Panel B shows robustness results using the Fama–French/Carhart four-factor (FF4) model. To compute cumulative abnormal returns, we use the FF3 or FF4 model with a rolling 252-daily estimation window (requiring a minimum of 126 days of data) to estimate factor betas. The cumulative return for each quarter is measured starting on the day of the $t + h$ revenue announcement and ending one day before the following revenue announcement date. The sample period spans from December 1996 through December 2023.

additional robustness results using the FF4 model to adjust returns. The findings are consistent with those obtained using the FF3 model.

The initial price dynamics we document are consistent with the findings in Lakonishok et al. (1994) and Skinner and Sloan (2002), which show that growth firms experience an asymmetrically large negative price reaction to negative surprises. These papers argue that the large price decline reflects overly optimistic expectations, resulting in subsequently negative returns when those expectations are not met. However, an important difference in our findings is that the initial large negative price reaction for software firms reverses within two quarters, indicating that investors were initially too pessimistic and ended up overreacting to revenue surprises. This result also differentiates our findings from the large literature on post-earnings announcement drift, as the price drift for software firms persists for several quarters.

B.2 Refining the classification of software companies

In this section, we refine our classification of software companies by expanding our criteria to include all firms that report any source of revenue from software products, rather than relying on a single classification based on the majority of revenue coming from software. We find that the magnitude of both analysts' forecast errors and factor alphas increases monotonically with the percentage of revenue attributed to software.

We utilize the FactSet RBICS with Revenue (2023) dataset to obtain the revenue percentages associated with each standardized reported business segment. From this dataset, we select all firms that create and sell software with varying degrees of software revenue contribution. We then sort these firms into low, medium, and high terciles based on the percentage of total revenue assigned to software by each company. These sorts are formed using the revenue information from each firm's most recent publicly available annual filing and are updated accordingly when a new annual filing becomes available. To avoid any forward-looking bias, we only use unrevised historical data. As this dataset is only available since July 2012, our analysis covers the period from July 2012 to December 2023.

Panel A of Table B.3 reports the analysts' mean forecast errors for firms in each of the low, medium, and high revenue share from software terciles. As a measure of analyst forecast, we use the median analysts' consensus. Companies that do not report revenues from software are labeled as "None" in the table. Across forecasting horizons (reported in each row in the table), we find a monotonic relationship between analysts' forecast errors and the percentage of total revenue assigned to software by each company. For example, at the fourth quarter horizon, firms in the lowest tercile, which derived an average of around 10% of their revenue from software, had a mean forecast error of approximately -0.48%, which is not statistically significant (t-statistic = -0.56). In contrast, firms in the medium and highest tercile, which derived 64% and 100% of their revenue from software products, have an average forecast error of 2.99% (t-statistic = 1.74) and 4.26% (t-statistic = 3.13), respectively. We also report the average forecast error of non-software companies, which is negative and equal to -2.15% (t-statistic = -2.78).

Panel B of Table B.3 reports the average mean returns and factor alphas for each of the software-revenue sorted groups, which are computed using equally-weighted portfolios. To form the portfolios, we update the sorts daily based on the percentage of revenue coming from software, using a one-day gap between the day of the ranking and the start of the holding period. We find a monotonic relationship between the factor alphas and the revenue percentage attributed to software terciles, consistent with results on the analysts' forecast errors. For example, the annualized FF3 alpha for the highest tercile is 5.05% (t-statistic = 3.00), the medium tercile is 0.79% (t-statistic = 0.15), while the

Table B.3. **Refining the Classification of Software Companies**

A: Analysts' mean forecast errors

	Revenue from software (median values)			
	0.00% None (1)	10% Low (2)	64% Medium (3)	100% High (4)
Forecast Horizon				
1 quarter	1.64	1.31	2.21	2.72
t-statistic	[6.51]	[3.43]	[3.13]	[9.44]
2 quarter	0.15	0.49	1.64	2.61
t-statistic	[0.32]	[0.75]	[1.74]	[4.31]
3 quarter	-1.20	0.03	1.19	3.23
t-statistic	[-1.93]	[0.04]	[0.89]	[3.40]
4 quarter	-2.15	-0.48	2.99	4.26
t-statistic	[-2.78]	[-0.56]	[1.74]	[3.13]

B: Performance measures and factor alphas

	Revenue from software (median values)			
	0.00% None (1)	10% Low (2)	64% Medium (3)	100% High (4)
Average return	11.52	10.83	15.00	19.20
Standard deviation	15.21	15.44	22.59	18.13
Three-factor alpha	-1.53	-1.57	0.65	4.85
t-statistic	[-1.87]	[-1.02]	[0.12]	[2.63]
Four-factor alpha	-1.27	-1.34	0.79	5.05
t-statistic	[-1.64]	[-0.95]	[0.15]	[3.00]

Notes: This table presents analysts' forecast errors and stock performance for firms sorted by the percentage of revenue derived from software products. We sort firms that generate revenue from software into low, medium, and high terciles based on the percentage of total revenue assigned to software by each company. Firms that do not report revenues from software are labeled as "None". Panel A reports the analysts' forecast errors for each of these groups, where forecast errors are computed as the difference between actual revenue and the median analyst consensus forecast, scaled by the actual revenue in the previous period. Panel B reports performance evaluation measures, including mean returns, FF3 and FF4 alphas for equally-weighted portfolios formed from each of these groups. Returns and alphas are annualized by multiplying monthly returns by 1,200. The t-statistics are reported in brackets. The sample spans from July 2012 to December 2023.

lowest tercile alpha is -1.34% (t-statistic = -0.95). Finally, the FF3 alpha for non-software companies is -1.27% (t-statistic = -1.64).

B.3 Customers of software

In this section, we investigate how market participants value non-software companies that are the primary customers of software firms and thus benefit the most from software usage. We find that these companies also experienced positive forecast errors and alphas, albeit significantly smaller in magnitude compared to those found for software companies.

To identify the primary customers of software companies, we utilize the FactSet Supply Chain Relationships (2023) database. This database employs information from SEC 10-K annual filings, investor presentations, and press releases to establish customer-supplier links between firms. Under rule SFAS 131, the U.S. Securities and Exchange Commission (SEC) requires companies to disclose their customers if their revenue exposure to them is 10% or greater. Consequently, the customers identified in our dataset play a significant role in the supplier firms' revenues. A key advantage of the FactSet dataset is that it not only uncovers the direct relationships that companies report but also the reverse relationships in which they are named in other companies' filings. This feature allows for a more comprehensive analysis of customer-supplier links.

As this dataset is only available since April 2003, we begin our analysis in April 2003 by identifying the key customers of software companies that are also included in the IBES/CRSP/Compustat datasets. To ensure that the software-firm-customer relationships are known to market participants at all times, we only update the supply chain relationships when an annual filing becomes publicly available, and we use historical, unrevised data. We conclude the selection process in December 2023.

Once we identify non-software companies that are customers of software companies, we measure the relevance of a customer-supplier relationship using the percentage of firms' revenues derived from their main customers during a given reporting period. Leveraging this information, we compute a measure of the relative importance of such relationships by dividing non-software companies into above- versus below-median bins based on those reported values. We also report results for non-software companies that do not provide this percentage for completeness.

Panel A of Table B.4 reports the analysts' mean forecast errors for customers of software companies, categorized by the strength of their customer-supplier relationship. Columns 4, 5, and 6 present the results for customers with high, low, and missing values for the relationship strength, respectively. Across forecasting horizons (reported in each row of the table), we find positive forecast errors only for non-software customers with a strong economic link to their software suppliers. For example, at the quarterly horizon, customers with above-median values have forecast errors of 1.38% (t-statistic = 2.21), compared to 0.60% (t-statistic = 1.97) for those with below-median values.

Panel B of Table B.4 presents the mean returns and factor alphas for the same group of companies. The key finding is that the factor alphas are positive and statistically significant only for non-software firms with strong customer links to software companies. For example, column 4 shows that the annualized three-factor alpha for customers with above-median values equals 2.27% (t-statistic = 1.90), which is smaller in magnitude than the alpha obtained for software companies (4.32%, t-statistic =2.26, column 1). In contrast, for the other groups of companies, including customers with a relatively weak link (column 5), those with no data on the link (column 6), and companies with no customer relation to software (column 2), the factor alphas are close to zero and not

Table B.4. **Supply Chain Relation to Software Firms**

A: Analysts' mean forecast errors

Forecast horizon	Software firms (1)	No relation (2)	Customers (3)	High (4)	Low (5)	No data (6)
		Supply chain relation to software firms		Relevance of the customer relation		
1 Quarter	2.47	1.69	1.09	1.38	0.60	1.10
t-statistic	[11.02]	[12.05]	[9.23]	[2.21]	[1.97]	[5.22]
2 Quarter	2.05	0.15	0.32	0.84	0.34	0.29
t-statistic	[3.78]	[0.63]	[1.83]	[1.57]	[0.64]	[0.69]
3 Quarter	2.63	-1.43	-0.31	0.39	-0.53	-0.34
t-statistic	[3.17]	[-3.82]	[-1.06]	[0.51]	[-0.68]	[-0.56]
4 Quarter	3.95	-2.37	-0.32	1.02	-1.04	-0.37
t-statistic	[3.26]	[-4.45]	[-0.90]	[1.36]	[-1.07]	[-0.53]

B: Performance measures and factor alphas

	Software firms (1)	No relation (2)	Customers (3)	High (4)	Low (5)	No data (6)
		Supply chain relation to software firms		Relevance of the customer relation		
Average return	17.42	10.76	13.12	13.89	11.36	13.27
Standard deviation	21.90	19.34	19.95	17.33	17.59	20.26
Three-factor alpha	4.32	-1.38	0.13	2.27	-0.54	0.18
t-statistic	[2.26]	[-0.95]	[0.12]	[1.90]	[-0.40]	[0.14]
Four-factor alpha	4.55	-0.77	0.70	2.71	-0.29	0.76
t-statistic	[2.43]	[-0.57]	[0.72]	[2.43]	[-0.22]	[0.72]

Notes: We rely on the FactSet supply chain relationship database to pinpoint the main customers of software companies. To evaluate the relevance of a customer-supplier relationship, we leverage the percentage of revenue that the software company obtained from this relationship during the reporting period. We then categorize firms into above- versus below-median bins based on the reported values. Panel A reports the mean cumulative forecast error for 4-quarter-ahead analysts' consensus forecasts. Panel B reports annualized alphas. The t-statistics are in brackets. The sample spans from April 2003 to December 2023.

statistically significant.

Overall, our analysis reveals significant growth surprises and abnormally high stock returns for firms that are positively impacted by software, which suggest the presence of predictable spillover effects on software companies' principal customers. This result is consistent with previous research (Hong et al., 2007; Cohen and Frazzini, 2008; Menzly and Ozbas, 2010) showing that relevant information affecting firm values diffuses only gradually across economically linked firms, leading to predictable patterns in both quantities, such as revenues, and stock prices.

B.4 Extending the sample to the 1970s

In our main analysis, we start our sample in 1996 due to the methodology used for classifying companies as software firms, which involves searching each company's annual revenue segment breakdowns in their 10-K filings and identifying those that derive more than 50 percent of their revenues from developing and selling software. However, the SEC only mandated electronic filing of financial reports in the EDGAR repository starting in 1995 or 1996, depending on the firm's size. As a result, accurately classifying software companies using the revenue share approach is only feasible from 1996 onward.

Software, however, existed long before 1996. The adoption of computers began in the 1970s (Greenwood and Jovanovic, 1999), utilizing various programming languages such as Unix, Fortran, COBOL, and FORMAC. In the 1980s, personal computers gained prominence, with Microsoft launching MS-DOS in the early 1980s and the first version of Microsoft Windows in 1985. By the 1990s, software was widespread, although it had not yet achieved the immense scalability it would later experience with the advent of cloud computing.

To extend our analysis back to the 1970s, we employ an alternative classification method based on the Standard Industrial Classification (SIC). Companies self-select their SIC codes based on their primary line of business. We take the SIC code 7372, Prepackaged Software, which is defined as "Establishments primarily engaged in the design, development, and production of prepackaged computer software" as our alternative classification method for software companies. In periods post-1996, where we have access to revenue segment breakdowns, approximately two-thirds of firms with the Prepackaged Software SIC code have more than 50 percent of their revenues coming from software. Moreover, Table B.5 ranks software companies based on the SIC codes and we find that 53.4% of all software companies also have the SIC code 7372 in any given year. This suggests that the broad SIC code 7372 allows us to capture a great share of software companies.

However, it is important to note that SIC code 7372 is not a perfect classification of software companies. Approximately one-third of Prepackaged Software firms are not accurately classified as software firms, as their revenue share from software offerings is below 50%. This is because their revenues include significant hardware, consulting, and/or service revenues which make up the majority of their revenues. Additionally, Table B.5 also shows that 46 percent of firms classified as software firms by FactSet's methodology come from other SIC industries, indicating that using the Prepackaged Software SIC code provides an incomplete classification of software companies. Nonetheless, on the whole, the rough classification still provides valuable insights into the outperformance of software companies in early periods and that this outperformance extends back to the 1970s.

Table B.6 shows the results for the extended 1976 to 2023 sample. Panel A reports mean returns and alphas using equally-weighted portfolios, while Panel B uses value-weighted portfolios. The main takeaway from Table B.6 is that a portfolio of Prepackaged Software companies produces substantial returns and alphas. Columns 3 and 5 show that it outperforms all non-prepackaged software companies and non-prepackaged growth companies, respectively, with factor alphas above 6% and t-statistics above 2.

Table B.7 provides a detailed breakdown of the returns for the prepackaged software portfolio from 1996 to 2023. Specifically, it categorizes companies with the SIC code 7372 (Prepackaged Software) into two distinct groups based on their revenue sources. The first group consists of prepackaged non-software companies, defined as those with SIC code 7372 but deriving less than 50% of their revenue from software. These companies primarily generate their revenue from hardware, consulting, and/or services. The second group comprises prepackaged (pure-play) software companies, characterized by SIC code 7372 with more than 50% of their revenue coming from software activities.

Table B.7 shows that the superior performance of prepackaged companies is attributable to those firms which derive the majority of their revenue from software offerings. Column 1 presents the returns and alphas for the prepackaged non-software companies. Here, the alpha values for both the value-weighted and equally-weighted returns are statistically insignificant from zero. Additionally, the point estimates for the equally-weighted portfolio (shown in Panel A) are negative. In stark contrast, Column 2 highlights the performance of (pure-play) prepackaged software companies, where the alphas are positive and statistically significant. Column 3 takes a long-short portfolio that is long the portfolio of prepackaged non-software companies and short prepackaged (pure-play) software companies. We document that the mean returns and alphas for this long-short portfolio are negative and statistically significant.

Overall, we find that Prepackaged Software companies have generated abnormally high stock returns relative to standard risk-factor models over the past five decades. Furthermore, we show that the outperformance of these companies, at least for the past two decades, is driven by Prepackaged Software companies that derive 50% or more of their revenue from software offerings.

Table B.5. **Proportion of Software Companies by SIC Codes**

Rank	Proportion of software companies	SIC	Description	Rank	Proportion of software companies	SIC	Description
1	53.37	7372	Prepackaged software	37	0.07	3823	Process control instruments
2	21.77	7370	Computer Programming, Data Processing	38	0.07	8742	Management consulting services
3	10.12	7373	Computer integrated systems design	39	0.07	5961	Catalog and mail-order houses
4	1.75	7374	Data processing and preparation	40	0.07	7323	Credit reporting services
5	1.20	6794	Patent owners and lessors	41	0.07	2836	Biological products, except diagnostic
6	1.03	7371	Custom computer programming services	42	0.07	3825	Instruments to measure electricity
7	0.93	5045	Computers, peripherals, and software	43	0.07	3651	Household audio and video equipment
8	0.76	3576	Computer Communications Equipment	44	0.05	7361	Employment agencies
9	0.69	3577	Computer peripheral equipment, nec	45	0.05	5122	Drugs, proprietaries, and sundries
10	0.57	4899	Communication services, nec	46	0.05	8700	Engineering, Accounting, Research, Management
11	0.53	7389	Business services, nec	47	0.05	4813	Telephone communication, except radio
12	0.52	3829	Measuring and controlling devices, nec	48	0.03	8721	Accounting, auditing, and bookkeeping
13	0.52	3674	Semiconductors and related devices	49	0.03	2890	Miscellaneous Chemical Products
14	0.41	3663	Radio and t.v. communications equipment	50	0.03	2834	Pharmaceutical preparations
15	0.41	3669	Communications equipment, nec	51	0.03	3571	Electronic computers
16	0.36	5734	Computer and software stores	52	0.03	5531	Auto and home supply stores
17	0.34	3661	Telephone and telegraph apparatus	53	0.03	9999	Nonclassifiable establishments
18	0.34	2741	Miscellaneous publishing	54	0.03	6799	Investors, nec
19	0.33	6211	Security brokers and dealers	55	0.03	6411	Insurance agents, brokers, and service
20	0.33	8200	Educational Services	56	0.03	4841	Cable and other pay television services
21	0.29	3679	Electronic components, nec	57	0.03	2750	Commercial Printing
22	0.29	3679	Electronic Components, NEC	58	0.02	3711	Motor vehicles and car bodies
23	0.29	3559	Special industry machinery, nec	59	0.02	3721	Aircraft
24	0.22	8731	Commercial physical research	60	0.02	7200	Personal Services
25	0.21	4812	Radiotelephone communication	61	0.02	7500	Automotive Repair, Services & Parking
26	0.19	3579	Office machines, nec	62	0.02	7812	Motion picture and video production
27	0.17	7310	Advertising	63	0.02	7830	Motion Picture Theaters
28	0.15	6282	Investment advice	64	0.02	2835	Diagnostic substances
29	0.15	6141	Personal credit institutions	65	0.02	6331	Fire, marine, and casualty insurance
30	0.15	4911	Electric services	66	0.02	3826	Analytical instruments
31	0.14	3578	Calculating and accounting equipment	67	0.02	8741	Management services
32	0.12	6099	Functions related to depository banking	68	0.02	8900	Services, NEC
33	0.12	5945	Hobby, toy, and game shops	69	0.02	3670	Electronic Components & Accessories
34	0.10	8071	Medical laboratories				
35	0.09	6531	Real estate agents and managers				
36	0.07	8090	Misc Health & Allied Services, NEC				

Notes: For our sample of software companies from 1996 to 2023, this table reports the percentage of firms belonging to each Standard Industrial Classification (SIC) code in a given year.

Table B.6. **Prepackaged Software Performance Evaluation and Alphas Extended Sample: Since the 1970s**

A: Equally-weighted returns	I	II		III	
	Prepackaged software (1)	Non-prepackaged software (2)	I - II (3)	Non-prepackaged growth (4)	I - III (5)
Average return	21.29	13.95	7.33	8.78	12.51
t-statistic	[4.99]	[5.83]	[2.49]	[3.11]	[5.31]
Standard deviation	31.28	18.88	18.81	24.25	14.67
Three-factor alpha	6.63	-0.30	6.92	-5.67	12.30
t-statistic	[2.75]	[-0.32]	[3.11]	[-4.76]	[5.75]
Four-factor alpha	8.46	1.24	7.22	-3.40	11.86
t-statistic	[3.27]	[1.13]	[3.38]	[-2.17]	[5.72]
B: Value-weighted returns	I	II		III	
	Prepackaged software (1)	Non-prepackaged software (2)	I - II (3)	Non-prepackaged growth (4)	I - III (5)
Average return	22.25	12.01	10.24	11.27	10.98
t-statistic	[5.26]	[6.24]	[3.05]	[4.63]	[3.46]
Standard deviation	29.43	15.39	21.46	17.59	19.88
Three-factor alpha	9.86	-0.53	10.39	0.07	9.79
t-statistic	[3.44]	[-2.30]	[3.61]	[0.12]	[3.41]
Four-factor alpha	9.89	-0.39	10.28	0.47	9.42
t-statistic	[3.71]	[-1.80]	[3.84]	[0.85]	[3.60]

Notes: This table presents performance evaluation measures and factor alphas for prepackaged software companies (SIC code equal to 7372), all non-prepackaged software companies, and non-prepackaged growth companies. In column (3) we form a long-short portfolio that buys the prepackaged software companies and sells all non-prepackaged software companies. In column (5) we form a long-short portfolio that buys the prepackaged software companies and sells non-prepackaged growth companies. Panel A reports results for equally-weighted portfolios, while Panel B reports results for value-weighted returns. We annualize all returns, expressed as a percentage per year, by multiplying monthly returns by 1,200. t-statistics are reported in brackets. The table spans the period from January 1976 through December 2023.

Table B.7. **Prepackaged Software vs. Software Companies Performance Evaluation and Alphas**

	I	II	
A: Equally-weighted returns	Prepackaged non-software (1)	Prepackaged software (2)	I - II (3)
Average return	12.89	18.54	-5.64
t-statistic	[2.24]	[3.47]	[-2.10]
Standard deviation	32.13	30.90	11.82
Three-factor alpha	-0.66	5.71	-6.37
t-statistic	[-0.24]	[1.88]	[-2.35]
Four-factor alpha	1.69	7.26	-5.57
t-statistic	[0.59]	[2.15]	[-2.49]
B: Value-weighted returns	I Prepackaged non-software (1)	II Prepackaged software (2)	I - II (3)
Average return	11.66	15.67	-4.01
t-statistic	[2.55]	[3.35]	[-1.88]
Standard deviation	22.94	26.04	15.53
Three-factor alpha	0.68	4.27	-3.59
t-statistic	[0.32]	[2.21]	[-1.47]
Four-factor alpha	1.75	4.29	-2.54
t-statistic	[0.89]	[2.18]	[-1.06]

Notes: This table presents performance evaluation measures and factor alphas for prepackaged non-software companies and prepackaged software companies. In column (3) we form a long-short portfolio that buys the prepackaged non-software companies and sells all prepackaged software companies. Panel A reports results for equally-weighted portfolios, while Panel B reports results for value-weighted returns. We annualize all returns, expressed as a percentage per year, by multiplying monthly returns by 1,200. t-statistics are reported in brackets. The table spans the period from January 1996 through December 2023.

Appendix C Learning about software

This section of the Appendix provides supplementary material for the Bayesian learning framework presented in Section 4 of the main text. It consists of the following sections:

C.1 Data

Section 4 of the main text uses quarterly revenue growth data for software and non-software companies, as well as monthly real per capita consumption growth data.

For the revenue series, we downloaded revenue data (revtq) from WRDS Compustat Quarterly fundamentals for all North American firms. We computed log differences to obtain quarterly growth rates for each firm and then seasonally adjusted the series. To calculate consumption growth rates, we used the seasonally adjusted real personal consumption expenditures on non-durables and services from the Bureau of Economic Analysis (2023) NIPA tables (Table 2.8.3 and Table 2.8.6). We converted this series to per capita terms using mid-quarter population data from NIPA Table 7.1 and then computed growth rates by taking log differences. While the revenue series is at a quarterly frequency, the consumption growth data is at a monthly frequency. Figure C.1 in Section C.6 depicts these series.

C.2 State-space representation of the cash-flow process

This section presents the state-space representation for the cash-flow process. As described in the main text, we assume that the revenue growth rates and consumption growth follow the specification given below:

$$\begin{aligned}
g_{c,t+1} &= \mu_c + x_t + \sigma_{c,t}\eta_{c,t+1}, \quad \eta_{c,t+1} \sim N(0,1), \\
x_{t+1} &= \rho x_t + \sqrt{1-\rho^2}\varphi_x \sigma_{c,t}\eta_{x,t+1}, \quad \eta_{x,t+1} \sim N(0,1), \\
g_{s,t+1} &= \mu_s + \phi_s x_t + \pi_s \sigma_{c,t}\eta_{c,t+1} + \sigma_{s,t}\epsilon_{s,t+1}, \quad \epsilon_{s,t+1} \sim N(0,1), \\
g_{ns,t+1} &= \mu_{ns} + \phi_{ns} x_t + \pi_{ns}\sigma_{c,t}\eta_{c,t+1} + \sigma_{ns,t}\epsilon_{ns,t+1}, \quad \epsilon_{ns,t+1} \sim N(0,1).
\end{aligned} \tag{C.1}$$

The state-space representation consists of a measurement equation and a state-transition equation. The measurement equation is given by:

$$y_{t+1} = A_{t+1}\left(H_0 + H_1 s_{t+1} + \nu_{t+1}\right) \quad \text{with} \quad \nu_{t+1} \sim N(0,R), \tag{C.2}$$

where A_{t+1} is a selection matrix that accounts for deterministic changes in y_{t+1}. This selection matrix is important due to the assumed measurement error model for consumption and the mixed-frequency nature of the growth series. The state vector is denoted by s_{t+1}.

The state-transition equation is:

$$s_{t+1} = F_0 + F_1 s_t + \nu_{t+1}(h_t) \quad \text{with} \quad \nu_{t+1}(h_t) \sim N(0, \Sigma_t) \tag{C.3}$$

where the law of motion for the conditional log volatility processes, h_t is given by:

$$h_{t+1} = \Psi h_t + w_{t+1} \text{ with } \quad w_{t+1} \sim N(0, \Sigma_h). \tag{C.4}$$

The matrices H_0, H_1, R, F_0, F_1, Σ_t, Ψ, and Σ_h depend on the model parameters, with Σ_t also depending on the time t conditional log volatility processes.

First, we describe the measurement equation, followed by a discussion of the state-transition equation and the law of motion for the conditional log volatility processes.

C.2.1 Measurement equation

The aggregate measurement equation in (C.2) combines the following individual measurement equations:

Measurement equation for consumption growth. As in Schorfheide et al. (2018) we incorporate monthly measurement errors in the consumption process that average out under temporal aggregation. In the main text, we assume these errors average out at the quarterly frequency.

Let the subscript t represent the monthly time as $t = 3(j-1) + m$, where m indexes the month within quarter j and $m = 1, 2, 3$. The measurement error model is specified as follows:

$$\begin{aligned} g^o_{c,3(j-1)+1} =& g_{c,3(j-1)+1} + \sigma_\epsilon \left(\epsilon_{3(j-1)+1} - \epsilon_{3(j-2)+3}\right) \\ & - \frac{1}{3} \sum_{m=1}^{3} \sigma_\epsilon \left(\epsilon_{3(j-1)+m} - \epsilon_{3(j-2)+m}\right) + \sigma^q_\epsilon \left(\epsilon^q_{(j)} - \epsilon^q_{(j-1)}\right), \\ g^o_{c,3(j-1)+m} =& g_{c,3(j-1)+m} + \sigma_\epsilon \left(\epsilon_{3(j-1)+m} - \epsilon_{3(j-1)+m-1}\right), \quad m = 2, 3. \end{aligned} \tag{C.5}$$

The series $g^o_{c,3(j-1)+1}$ with the "o" superscript represents the observed consumption growth series, which contains measurement errors. The series $g_{c,3(j-1)+1}$ without the "o" superscript denotes the true measure of consumption growth. The parameters σ_ϵ and σ^q_ϵ represent the standard deviations of monthly and quarterly consumption measurement errors, respectively.

When aggregating the monthly consumption series to the quarterly frequency using the following equation:

$$g^q_{c,(j)} = c^q_{(j)} - c^q_{(j-1)} = \sum_{\tau=1}^{5} \left(\frac{3 - |\tau - 3|}{3}\right) g_{c,3j-\tau+1}. \tag{C.6}$$

the monthly measurement errors are averaged out, resulting in

$$g^{q,o}_{c,(j)} = g^q_{c,(j)} + \sigma^q_\epsilon \left(\epsilon^q_{(j)} - \epsilon^q_{(j-1)}\right).$$

Measurement equation for revenue growth. We assume that the revenue growth series for software and non-software companies are measured without any measurement errors, denoted as:

$$\begin{aligned} g^{o,q}_{s,(j)} &= g^{q}_{s,(j)} \\ g^{o,q}_{ns,(j)} &= g^{q}_{ns,(j)} \end{aligned} \tag{C.7}$$

Agents observe these series every quarter j. To link the quarterly series to the monthly frequency of the model, we use the following temporal aggregation function:

$$g^{q}_{i,(j)} = \sum_{\tau=1}^{5} \left(\frac{3 - |\tau - 3|}{3} \right) g_{i,3j-\tau+1} \quad \text{for} \quad i \in \{s, ns\}. \tag{C.8}$$

Assuming that $t+1$ is the last month of the quarter, we can combine the individual measurement equations together with equation (C.1) and express them in matrix form as follows:

$$y_{t+1} = \begin{bmatrix} g^{o}_{c,t+1} \\ g^{o}_{c,t} \\ g^{o}_{c,t-1} \\ g^{q,o}_{s,t+1} \\ g^{q,o}_{ns,t+1} \end{bmatrix}, \quad A_{t+1} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}.$$

In order to obtain an expression for the matrices related to the measurement equation, we first define the vectors of states s_{t+1}

$$\begin{aligned} s_{t+1} = \big[& x_{t+1},\ x_t,\ x_{t-1},\ x_{t-2},\ x_{t-3},\ x_{t-4},\ \sigma_{c,t}\eta_{c,t+1},\ \sigma_{c,t-1}\eta_{c,t},\ \sigma_{c,t-2}\eta_{c,t-1},\ \sigma_{c,t-3}\eta_{c,t-2},\ \sigma_{c,t-4}\eta_{c,t-3}, \\ & \sigma_{\epsilon}\epsilon_{t+1},\ \sigma_{\epsilon}\epsilon_{t},\ \sigma_{\epsilon}\epsilon_{t-1},\ \sigma_{\epsilon}\epsilon_{t-2},\ \sigma_{\epsilon}\epsilon_{t-3},\ \sigma_{\epsilon}\epsilon_{t-4},\ \sigma^{q}_{\epsilon}\epsilon^{q}_{t+1},\ \sigma^{q}_{\epsilon}\epsilon^{q}_{t},\ \sigma^{q}_{\epsilon}\epsilon^{q}_{t-1},\ \sigma^{q}_{\epsilon}\epsilon^{q}_{t-2}, \\ & \sigma_{s,t}\eta_{s,t+1},\ \sigma_{s,t-1}\eta_{s,t},\ \sigma_{s,t-2}\eta_{s,t-1},\ \sigma_{s,t-3}\eta_{s,t-2},\ \sigma_{s,t-4}\eta_{s,t-3}, \\ & \sigma_{ns,t}\eta_{ns,t+1},\ \sigma_{ns,t-1}\eta_{ns,t},\ \sigma_{ns,t-2}\eta_{ns,t-1},\ \sigma_{ns,t-3}\eta_{ns,t-2},\ \sigma_{ns,t-4}\eta_{ns,t-3} \big]'. \end{aligned}$$

Given s_{t+1}, we write the matrices H_0, H_1, and R as follows:

$$H_1 = \left[\begin{array}{ccccccccccccccccccccc} 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -\frac{1}{3} & -\frac{1}{3} & \frac{2}{3} & -\frac{2}{3} & \frac{1}{3} & \frac{1}{3} & 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & \frac{\phi_s}{3} & \frac{2\phi_s}{3} & \phi_s & \frac{2\phi_s}{3} & \frac{\phi_s}{3} & \frac{\pi_s}{3} & \frac{2\pi_s}{3} & \pi_s & \frac{2\pi_s}{3} & \frac{\pi_s}{3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{\phi_{ns}}{3} & \frac{2\phi_{ns}}{3} & \phi_{ns} & \frac{2\phi_{ns}}{3} & \frac{\phi_{ns}}{3} & \frac{\pi_{ns}}{3} & \frac{2\pi_{ns}}{3} & \pi_{ns} & \frac{2\pi_{ns}}{3} & \frac{\pi_{ns}}{3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{array} \right.$$

$$\left. \begin{array}{cccccccccc} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \frac{1}{3} & \frac{2}{3} & 1 & \frac{2}{3} & \frac{1}{3} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{3} & \frac{2}{3} & 1 & \frac{2}{3} & \frac{1}{3} \end{array} \right]$$

$$
H_0 = \begin{bmatrix} \mu_c \\ \mu_c \\ \mu_c \\ \mu_c \\ \mu_c \\ 3\mu_s \\ 3\mu_{ns} \end{bmatrix}, \quad R = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \left(\sigma^q_{s,\epsilon}\right)^2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \left(\sigma^q_{ns,\epsilon}\right)^2 \end{bmatrix},
$$

where we allow for some fixed small measurement errors for revenue growth rates of software and non-software companies.

C.2.2 State-transition equations

Next, we derive the coefficients of the state transition equations:

$$
\begin{aligned}
s_{t+1} &= F_0 + F_1 s_t + \nu_{t+1}(h_t) \quad \text{with} \quad \nu_{t+1}(h_t) \sim N(0, \Sigma_t) \\
h_{t+1} &= \Psi h_t + w_{t+1} \text{ with} \quad w_{t+1} \sim N(0, \Sigma_h).
\end{aligned}
$$

Given s_{t+1}, we write the matrices F_0, F_1, and Σ_t as follows: F_0 is vector of zeros of size 31.

$$
F_1 = \begin{bmatrix}
\rho & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0
\end{bmatrix}
$$

Σ_t is a 31×31 matrix with zeros in every entry expect: $\Sigma_{t,[1,1]} = (1-\rho^2)\varphi_x^2 \sigma_{c,t}^2$; $\Sigma_{t,[7,7]} = \sigma_{c,t}^2$; $\Sigma_{t,[12,12]} = \sigma_\epsilon^2$; $\Sigma_{t,[18,18]} = (\sigma_\epsilon^q)^2$; $\Sigma_{t,[22,22]} = \sigma_{s,t}^2$; $\Sigma_{t,[27,27]} = \sigma_{ns,t}^2$.

Finally, the matrices associated with the persistent conditional log volatility processes

$h_t = [h_{c,t}, h_{s,t}, h_{ns,t}]'$, can be written as

$$\Psi = \begin{bmatrix} \rho_{h_c} & 0 & 0 \\ 0 & \rho_{h_s} & 0 \\ 0 & 0 & \rho_{h_{ns}} \end{bmatrix}, \quad \Sigma_h = \begin{bmatrix} \sigma^2_{h_c}(1-\rho^2_{h_c}) & 0 & 0 \\ 0 & \sigma^2_{h_s}(1-\rho^2_{h_s}) & 0 \\ 0 & 0 & \sigma^2_{h_{ns}}(1-\rho^2_{h_{ns}}) \end{bmatrix}, \quad \omega_{t+1} = \begin{bmatrix} \omega_{c,t+1} \\ \omega_{s,t+1} \\ \omega_{ns,t+1} \end{bmatrix},$$

with $\sigma_{i,t} = \varphi_i \sigma \exp(h_{i,t})$ for $i = \{c, s, ns\}$ and $\varphi_c = 1$.

C.3 Posterior inference

This section provides a detailed description of the Metropolis-within-Gibbs algorithm used to sample from the joint posterior of the model parameters and latent states. We define the following parameter vectors:

$$\Theta_{cf} = [\mu_c, \rho, \varphi_x, \sigma, \sigma_\epsilon, \sigma^q_\epsilon, \mu_s, \phi_s, \pi_s, \varphi_s, \mu_{ns}, \phi_{ns}, \pi_{ns}, \varphi_{ns}]',$$
$$\Theta_h = [\rho_{h_c}, \sigma_{h_c}, \rho_{h_s}, \sigma_{h_s}, \rho_{h_{ns}}, \sigma_{h_{ns}}]',$$

where Θ_{cf} contains the parameters related to the cash-flow process, and Θ_h includes the parameters associated with the conditional log volatility processes. Additionally, let $x_{0:T}$ and $h_{0:T}$ denote the sequences of latent states and latent volatilities, respectively, from time 0 to T. The complete set of parameters and latent states in the model is represented by $\Theta = (\Theta_{cf}, \Theta_h, x_{0:T}, h_{0:T})$.

To perform Bayesian inference about Θ and the latent state vector, we first specify a prior distribution $p(\Theta)$ given by:

$$\begin{aligned}
&\mu_c \sim N\left(\tilde{\mu}_c, \tilde{\sigma}^2_{\mu_c}\right), && \rho \sim N^T\left(\tilde{\rho}, \tilde{\sigma}^2_{\rho}\right), && \varphi_x \sim N\left(\tilde{\varphi}_x, \tilde{\sigma}^2_{\varphi_x}\right), && \sigma \sim \mathcal{IG}(\tilde{\alpha_c}, \tilde{\beta_c}), \\
&\mu_i \sim N\left(\tilde{\mu}_i, \tilde{\sigma}^2_{\mu_i}\right), && \phi_i \sim N\left(\tilde{\phi}_i, \tilde{\sigma}^2_{\phi_i}\right), && \pi_i \sim N\left(\tilde{\pi}_i, \tilde{\sigma}^2_{\pi_i}\right), && \varphi_i \sim N\left(\tilde{\varphi}_i, \tilde{\sigma}^2_{\varphi_i}\right), \\
&\rho_{h_c} \sim N^T\left(\tilde{\rho}_{h_c}, \tilde{\sigma}^2_{\rho_{h_c}}\right), && \sigma^2_{h_c} \sim \mathcal{IG}(\tilde{\alpha_{h_c}}, \tilde{\beta_{h_c}}) && \rho_{h_i} \sim N^T\left(\tilde{\rho}_{h_i}, \tilde{\sigma}^2_{\rho_{h_i}}\right), && \sigma^2_{h_i} \sim \mathcal{IG}(\tilde{\alpha_{h_i}}, \tilde{\beta_{h_i}}) \\
&\sigma_\epsilon \sim \mathcal{IG}(\tilde{\alpha_\epsilon}, \tilde{\beta_\epsilon}), && \sigma^q_\epsilon \sim \mathcal{IG}(\tilde{\alpha_{\epsilon_q}}, \tilde{\beta_{\epsilon_q}})
\end{aligned}$$

for $i \in \{s, ns\}$ and N, N^T, and $\mathcal{IG}$ represent the normal, truncated (outside of the $(-1, 1)$ interval) normal, and inverse gamma distributions, respectively. We centered the priors in 1996Q1 around the posterior median estimates of the model using data from 1961Q1 to 1995Q4. Additionally, we set the priors for software parameters equal to the pre-1996 non-software parameter estimates.

After specifying the prior distribution, we update our prior beliefs about the parameter vector Θ based on the sample information $Y^T = \{g_{c,1:T},\ g^q_{s,1:T},\ g^q_{ns,1:T}\}$. The updated knowledge regarding Θ is summarized by the posterior distribution $p(\Theta \mid Y)$, which is linked to the prior distribution through Bayes' theorem:

$$p\left(\Theta \mid Y^T\right) = \frac{p\left(Y^T \mid \Theta\right) p(\Theta)}{p\left(Y^T\right)}.$$

We employ a Metropolis-within-Gibbs algorithm to sample from $p\left(\Theta \mid Y^T\right)$. We initiate the process with an initial guess of the parameter vector, denoted as $\Theta^{(0)}$. Given a draw

$\Theta^{(k-1)}$, we generate the next draw $\Theta^{(k)}$ using the following three steps:

1. We draw $\Theta_{cf}^{(k)}$ conditional on $\left(Y^T, \Theta_h^{(k-1)}, h_{0:T}^{(k-1)}\right)$ from its posterior distribution using a Metropolis-Hastings step, where we use the Kalman filter to evaluate the likelihood $p\left(Y^T \mid \Theta_{cf}^{(k)}, h_{0:T}^{(k-1)}\right)$ and to obtain $x_{0:T}^{(k)}$.

2. We draw the sequence of stochastic volatilities $h_{0:T-1}^{(k)}$ conditional on $\left(Y^T, \Theta_{cf}^{(k)}, \Theta_h^{(k-1)}\right)$ using the Kim, Shephard, and Chib (1998) algorithm.

3. We use a Gibbs sampling step to draw $\Theta_h^{(k)}$ conditional on $\left(Y^T, H_{0:T}^{(k)}, \Theta_{cf}^{(k)}\right)$

This algorithm is iterated to generate 10,000 draws from the posterior distribution of the parameters and states at each time T.

C.4 Model-implied forecasts

This section aggregates the model-implied forecasts from a monthly to a quarterly frequency. These model-implied quarterly forecasts can then be compared with the quarterly forecasts produced by analysts used in the empirical section of the paper.

To set the notation, let $Y_{(j)}^{qrt}$ denote the revenue for quarter j which is defined as the sum of monthly revenue over the span of that quarter, that is,

$$Y_{(j)}^{qrt} = Y_{3(j-1)+1}^{mthly} + Y_{3(j-1)+2}^{mthly} + Y_{3(j-1)+3}^{mthly},$$

where $Y_{3(j-1)+m}^{mthly}$ denotes the revenue for month m within that quarter. Next, log-linearize $Y_{(j)}^{qrt}$ around a monthly value Y_*:

$$log(Y_{(j)}^{qrt}) \approx log(3Y_*) + \frac{1}{3Y_*}\left(Y_{3(j-1)+1}^{mthly} - Y_*\right) + \frac{1}{3Y_*}\left(Y_{3(j-1)+2}^{mthly} - Y_*\right) + \frac{1}{3Y_*}\left(Y_{3(j-1)+3}^{mthly} - Y_*\right).$$

Denote with lowercases percentage deviations from the log-linearization point to obtain (i.e., $y = \frac{Y}{Y_*} \approx \frac{Y-Y_*}{Y_*}$)

$$y_{(j)}^{qrt} \approx \frac{1}{3}\left(y_{3(j-1)+1}^{mthly} + y_{3(j-1)+2}^{mthly} + y_{3(j-1)+3}^{mthly}\right),$$

To simplify notation let $t+1$ be the first month of quarter j, then it follows that the revenue growth rate from quarter $j-1$ to quarter j is equal to the sum of monthly revenue growth rates:

$$\begin{aligned} g_{y,(j)}^{qrt} = y_{(j)}^{qrt} - y_{(j-1)}^{qrt} &= \frac{1}{3}\sum_{m=1}^{3} y_{3(j-1)+m}^{mthly} - \frac{1}{3}\sum_{m=1}^{3} y_{3(j-2)+m}^{mthly} \\ &= \frac{1}{3}\left(y_{t+3} + y_{t+2} + y_{t+1}\right) - \frac{1}{3}\left(y_t + y_{t-1} + y_{t-2}\right) \\ &= \frac{1}{3}g_{y,t+3} + \frac{2}{3}g_{y,t+2} + g_{y,t+1} + \frac{2}{3}g_{y,t} + \frac{1}{3}g_{y,t-1} \end{aligned} \tag{C.9}$$

where in the last line we define the monthly revenue growth as the log difference in revenue between two consecutive months (i.e., $g_{y,t} = y_t - y_{t-1}$). We can then take time t conditional expectations to obtain 1-quarter forecasts:

$$\mathbb{E}_t g_{y,(j)}^{qrt} = \mathbb{E}_t y_{(j)}^{qrt} - y_{(j-1)}^{qrt} = \frac{1}{3}\mathbb{E}_t g_{y,t+3} + \frac{2}{3}\mathbb{E}_t g_{y,t+2} + \mathbb{E}_t g_{y,t+1} + \frac{2}{3} g_{y,t} + \frac{1}{3} g_{y,t-1} \tag{C.10}$$

Equations (C.9) and (C.10) are directly comparable to our empirical analysis, since there we also scaled both actuals and forecasts for quarter j by the actual revenue value realized in quarter $j-1$. This revenue value is included in the forecasters' information sets when issuing the forecast.

Given (C.9) and (C.10) the 1-quarter forecast error is equal to:

$$g_{y,(j)}^{qrt} - \mathbb{E}_t g_{y,(j)}^{qrt} = \frac{1}{3}\left(g_{y,t+3} - \mathbb{E}_t g_{y,t+3}\right) + \frac{2}{3}\left(g_{y,t+2} - \mathbb{E}_t g_{y,t+2}\right) + \left(g_{y,t+1} - \mathbb{E}_t g_{y,t+1}\right)$$

We can compute in a similar way the model-implied forecast and forecast errors for a 2-quarter forecast horizon. Let $t+1$ be the first month of quarter j. Then, the actual 2-quarter growth rate is given by:

$$\begin{aligned} y_{(j+1)}^{qrt} - y_{(j-1)}^{qrt} &= \frac{1}{3}\left(y_{t+6} + y_{t+5} + y_{t+4}\right) - \frac{1}{3}\left(y_t + y_{t-1} + y_{t-2}\right) \\ &= \frac{1}{3} g_{y,t+6} + \frac{2}{3} g_{y,t+5} + g_{y,t+4} + \cdots + g_{y,t+1} + \frac{2}{3} g_{y,t} + \frac{1}{3} g_{y,t-1} \end{aligned} \tag{C.11}$$

Taking time t conditional expectations, we obtain the 2-quarter forecast:

$$\mathbb{E}_t y_{(j+1)}^{qrt} - y_{(j-1)}^{qrt} = \frac{1}{3}\mathbb{E}_t g_{y,t+6} + \frac{2}{3}\mathbb{E}_t g_{y,t+5} + \mathbb{E}_t g_{y,t+4} + \cdots + \mathbb{E}_t g_{y,t+1} + \frac{2}{3} g_{y,t} + \frac{1}{3} g_{y,t-1} \tag{C.12}$$

Finally, using equations (C.11) and (C.12), we can compute the 2-quarter horizon forecast error:

$$\begin{aligned} y_{(j+1)}^{qrt} - \mathbb{E}_t y_{(j+1)}^{qrt} &= \frac{1}{3}\left(g_{y,t+6} - \mathbb{E}_t g_{y,t+6}\right) + \frac{2}{3}\left(g_{y,t+5} - \mathbb{E}_t g_{y,t+5}\right) \\ &+ \left(g_{y,t+4} - \mathbb{E}_t g_{y,t+4}\right) + \cdots + \left(g_{y,t+1} - \mathbb{E}_t g_{y,t+1}\right) \end{aligned} \tag{C.13}$$

Next, we compute the model-implied forecast and forecast errors for a 3-quarter forecast horizon. Let $t+1$ be the first month of quarter j. Then, the actual 3-quarter growth rate is given by:

$$\begin{aligned} y_{(j+2)}^{qrt} - y_{(j-1)}^{qrt} &= \frac{1}{3}\left(y_{t+9} + y_{t+8} + y_{t+7}\right) - \frac{1}{3}\left(y_t + y_{t-1} + y_{t-2}\right) \\ &= \frac{1}{3} g_{y,t+9} + \frac{2}{3} g_{y,t+8} + g_{y,t+7} + \cdots + g_{y,t+1} + \frac{2}{3} g_{y,t} + \frac{1}{3} g_{y,t-1}. \end{aligned} \tag{C.14}$$

Taking time t conditional expectations, we obtain the 3-quarter forecast:

$$\mathbb{E}_t y_{(j+2)}^{qrt} - y_{(j-1)}^{qrt} = \frac{1}{3}\mathbb{E}_t g_{y,t+9} + \frac{2}{3}\mathbb{E}_t g_{y,t+8} + \mathbb{E}_t g_{y,t+7} + \cdots + \mathbb{E}_t g_{y,t+1} + \frac{2}{3} g_{y,t} + \frac{1}{3} g_{y,t-1}. \tag{C.15}$$

Finally, using equations (C.14) and (C.15), we can compute the 3-quarter horizon forecast error:

$$y^{qrt}_{(j+2)} - \mathbb{E}_t y^{qrt}_{(j+2)} = \frac{1}{3}\left(g_{y,t+9} - \mathbb{E}_t g_{y,t+9}\right) + \frac{2}{3}\left(g_{y,t+8} - \mathbb{E}_t g_{y,t+8}\right) \\ + \left(g_{y,t+7} - \mathbb{E}_t g_{y,t+7}\right) + \cdots + \left(g_{y,t+1} - \mathbb{E}_t g_{y,t+1}\right). \tag{C.16}$$

Finally, the actual 4-quarter growth rate is given by:

$$\begin{aligned} y^{qrt}_{(j+3)} - y^{qrt}_{(j-1)} &= \frac{1}{3}\left(y_{t+12} + y_{t+11} + y_{t+10}\right) - \frac{1}{3}\left(y_t + y_{t-1} + y_{t-2}\right) \\ &= \frac{1}{3} g_{y,t+12} + \frac{2}{3} g_{y,t+11} + g_{y,t+10} + \cdots + g_{y,t+1} + \frac{2}{3} g_{y,t} + \frac{1}{3} g_{y,t-1}. \end{aligned} \tag{C.17}$$

Taking time t conditional expectations, we obtain the 3-quarter forecast:

$$\mathbb{E}_t y^{qrt}_{(j+3)} - y^{qrt}_{(j-1)} = \frac{1}{3}\mathbb{E}_t g_{y,t+12} + \frac{2}{3}\mathbb{E}_t g_{y,t+11} + \mathbb{E}_t g_{y,t+10} + \cdots + \mathbb{E}_t g_{y,t+1} + \frac{2}{3} g_{y,t} + \frac{1}{3} g_{y,t-1}. \tag{C.18}$$

Finally, using equations (C.17) and (C.18), we can compute the 4-quarter horizon forecast error:

$$y^{qrt}_{(j+3)} - \mathbb{E}_t y^{qrt}_{(j+3)} = \frac{1}{3}\left(g_{y,t+12} - \mathbb{E}_t g_{y,t+12}\right) + \frac{2}{3}\left(g_{y,t+11} - \mathbb{E}_t g_{y,t+11}\right) \\ + \left(g_{y,t+10} - \mathbb{E}_t g_{y,t+10}\right) + \cdots + \left(g_{y,t+1} - \mathbb{E}_t g_{y,t+1}\right). \tag{C.19}$$

We can derive analytic expressions for these equations using the assumed processes for growth rates from equation (2) in the main text and by computing conditional expectations.

C.5 Solving the model

This section provides a solution of the model. The endowment process is given by:

$$\begin{aligned} & g_{c,t+1} = \mu_c + x_t + \sigma_{c,t}\eta_{c,t+1}, \quad \eta_{c,t+1} \sim N(0,1), \\ & x_{t+1} = \rho x_t + \sqrt{1-\rho^2}\varphi_x \sigma_{c,t}\eta_{x,t+1}, \quad \eta_{x,t+1} \sim N(0,1), \\ & g_{s,t+1} = \mu_s + \phi_s x_t + \pi_s \sigma_{c,t}\eta_{c,t+1} + \sigma_{s,t}\epsilon_{s,t+1}, \quad \epsilon_{s,t+1} \sim N(0,1), \\ & g_{ns,t+1} = \mu_{ns} + \phi_{ns} x_t + \pi_{ns}\sigma_{c,t}\eta_{c,t+1} + \sigma_{ns,t}\epsilon_{ns,t+1}, \quad \epsilon_{ns,t+1} \sim N(0,1), \\ & \sigma^2_{i,t+1} = (\varphi_i\sigma)^2 + \nu_i\left(\sigma^2_{i,t} - (\varphi_i\sigma)^2\right) + \sigma_{\omega_i}\omega_{i,t+1}, \quad \omega_{i,t+1} \sim N(0,1), \quad \text{for} \quad i \in \{c, s, ns\}, \end{aligned}$$

where the last equation uses the Schorfheide et al. (2018) linear approximation of the volatility process around the unconditional mean of h, with $\sigma_{\omega_i} = 2\left(\varphi_i\sigma\right)^2 \sigma_{h_i}$ and $\nu_i = \rho_{h_i}$.

Given the Epstein-Zin preference for the representative agent, the logarithm of the real stochastic discount factor (SDF) is given by:

$$m_{t+1} = \theta \log\delta - \frac{\theta}{\psi} g_{c,t+1} + (\theta - 1) r_{c,t+1} \tag{C.20}$$

with $\theta = \frac{1-\gamma}{1-\frac{1}{\psi}}$ and $r_{c,t+1}$ denotes the log return on the consumption claim, which using the approximation of Campbell and Shiller (1988) is given by:

$$r_{c,t+1} = \kappa_0 + \kappa_1 pc_{t+1} - pc_t + g_{c,t+1}. \tag{C.21}$$

The variable pc_{t+1} represents the log price-to-consumption ratio, and κ_0 and κ_1 are constants that depend on the unconditional mean of the price-consumption ratio, $\bar{pc}$:

$$\kappa_1 = \frac{\exp(\bar{pc})}{1+\exp(\bar{pc})} \quad \text{and} \quad \kappa_0 = \log(1+\exp(\bar{pc})) - \kappa_1 \bar{pc}.$$

The Euler equation is:

$$\mathbb{E}_t \left[\exp\left(m_{t+1} + r_{t+1}\right)\right] = 1, \tag{C.22}$$

We employ this equation to price the consumption claim in Section C.5.1 and to price the cash-flow claims for software and non-software companies in Section C.5.4.

C.5.1 Consumption claim

We conjecture that the price-consumption ratio is linear in the state variables:

$$pc_t = A_0 + A_1 x_t + A_2 \sigma^2_{c,t} \tag{C.23}$$

To determine the coefficients As, we substitute the log-linear approximation for $r_{c,t+1}$ from equation (C.21) and the SDF from equation (C.20) into the Euler Equation given in (C.22). Then, by applying the method of undetermined coefficients, we obtain:

$$\begin{aligned}
A_1 &= \frac{1-\frac{1}{\psi}}{1-\kappa_1 \rho}, \\
A_2 &= \frac{\theta}{2(1-\kappa_1 \nu_c)} \left[\left(1-\frac{1}{\psi}\right)^2 + \left(\kappa_1 A_1 (\sqrt{1-\rho^2}\varphi_x\right)^2 \right], \\
A_0 &= \frac{1}{1-\kappa_1} \left[\log\delta + \kappa_0 + \mu_c \left(1-\frac{1}{\psi}\right) + \kappa_1 A_2 \left(1-\nu_c\right) \left(\varphi_c \sigma\right)^2 + \frac{\theta}{2} \left(\kappa_1 A_2\right)^2 \sigma^2_{\omega_c} \right].
\end{aligned} \tag{C.24}$$

To finalize the derivation of the price-consumption ratio, we must determine the steady-state value of pc_t. This requires solving the following system of equations:

$$\begin{aligned}
\bar{pc} &= A_0\left(\bar{pc}\right) + A_2\left(\bar{pc}\right)\left(\varphi_c \sigma\right)^2, \\
\kappa_1 &= \frac{\exp(\bar{pc})}{1+\exp(\bar{pc})}, \\
\kappa_0 &= \log(1+\exp(\bar{pc})) - \kappa_1 \bar{pc}.
\end{aligned}$$

This system of equations can be solved numerically to find the value of $\bar{pc}$.

We next proceed to derive an expression for the real and nominal SDF that will be used when pricing the software and non-software cash-flow streams.

C.5.2 Real and nominal SDF

By substituting equation (C.21) and equation (C.23) into (C.20), we can express the real stochastic discount factor (SDF) in terms of the state variables and the underlying shocks:

$$\begin{aligned}m_{t+1} =&(\theta-1)\left[\kappa_0 + A_0(\kappa_1-1) + \kappa_1 A_2(1-\nu_c)(\varphi_c\sigma)^2\right] - \gamma\mu_c + \theta\log\delta \\ &- \frac{1}{\psi}x_t + (\theta-1)A_2(\kappa_1\nu_c-1)\sigma_{c,t}^2 \\ &- \gamma\sigma_{c,t}\eta_{c,t+1} - (1-\theta)\kappa_1 A_1\sqrt{1-\rho^2}\varphi_x\sigma_{c,t}\eta_{x,t+1} - (1-\theta)\kappa_1 A_2\sigma_{w_c}w_{c,t+1}.\end{aligned} \tag{C.25}$$

Shocks to the real SDF can be written as:

$$m_{t+1} - \mathbb{E}_t[m_{t+1}] = -\lambda_c\sigma_{c,t}\eta_{c,t+1} - \lambda_x\sigma_{x,t}\eta_{x,t+1} - \lambda_{w_c}\sigma_{w_c}w_{c,t+1} \tag{C.26}$$

where the λ's denote the market prices of risk:

$$\lambda_c = \gamma, \qquad \lambda_x = (1-\theta)\kappa_1 A_1\sqrt{1-\rho^2}\varphi_x, \qquad \lambda_{w_c} = (1-\theta)\kappa_1 A_2.$$

We use the nominal discount factor to price nominal payoffs. It can be obtained by subtracting the inflation rate, π_{t+1}, from the real discount factor, m_{t+1}:

$$m_{t+1}^{\$} = m_{t+1} - \pi_{t+1}, \tag{C.27}$$

where we use the the dollar sign superscript, "\$", to distinguish nominal from real values. For simplicity, and because it is not relevant for the results, we assume that the inflation rate is constant, i.e., $\pi_{t+1} = \bar{\pi}$.

We will now derive an expression for the one-period risk-free rate, which will be useful when computing realized mean excess returns for software and non-software companies.

C.5.3 Risk-free rate

The risk-free rate is affine in the state variables and given by:

$$\begin{aligned}r_{f,t} =& -\mathbb{E}_t(m_{t+1}) - \frac{1}{2}\mathrm{Var}_t(m_{t+1}) \\ =& -\theta\log\delta + \gamma\mu_c + (1-\theta)\left[\kappa_0 + A_0(\kappa_1-1) + \kappa_1 A_2(1-\nu_c)(\varphi_c\sigma)^2\right] - \frac{1}{2}((1-\theta)\kappa_1 A_2)^2\sigma_{w_c}^2 \\ &+ \frac{1}{\psi}x_t + \left((1-\theta)A_2(\kappa_1\nu_c-1) - \frac{1}{2}\gamma^2 - \frac{1}{2}\left((1-\theta)\kappa_1 A_1\sqrt{1-\rho^2}\varphi_x\right)^2\right)\sigma_{c,t}^2.\end{aligned} \tag{C.28}$$

C.5.4 Software and non-software cash-flow claims

We now present asset-pricing solutions for the claim on software cash-flows. The solutions for non-software companies can be derived similarly by substituting the s subscript with the ns subscript.

First, we log-linearize the return on software. Let $D_{s,t+1}$ be the aggregate dividends paid by software companies and $P_{s,t+1}$ be the stock price. The return on software is given by:

$$R_{s,t+1} = \frac{P_{s,t+1} + D_{s,t+1}}{P_{s,t}} = \frac{1 + \frac{P_{s,t+1}}{D_{s,t+1}}}{\frac{P_{s,t}}{D_{s,t}}} \frac{D_{s,t+1}}{D_{s,t}}. \tag{C.29}$$

Assuming the relation between dividends and revenue is $D_{s,t+1} = Y_{s,t+1}^{\lambda}$, where λ denotes the elasticity of dividends to changes in revenues (i.e., $\frac{\%\Delta D}{\%\Delta Y}$), we log-linearize this equation around $\bar{pd}_s$, yielding:

$$r_{s,t+1} = \kappa_{0,s} + \kappa_{1,s} pd_{s,t+1} - pd_{s,t} + \lambda g_{s,t+1}, \tag{C.30}$$

where the log-linearization parameters are given by

$$\kappa_{1,s} = \frac{\exp(\bar{pd}_s)}{1 + \exp(\bar{pd}_s)} \quad \text{and} \quad \kappa_{0,s} = \log(1 + \exp(\bar{pd}_s)) - \kappa_{1,s}\bar{pd}_s.$$

The Euler equation that prices the nominal software return $r_{s,t+1}$ is:

$$\mathbb{E}_t \left[\exp\left(m_{t+1}^{\$} + r_{s,t+1}\right)\right] = 1. \tag{C.31}$$

To solve this equation, we conjecture that the price-dividend ratio takes the form:

$$pd_{s,t} = A_{0,s} + A_{1,s} x_t + A_{2,s,c}\sigma_{c,t}^2 + A_{2,s,s}\sigma_{s,t}^2. \tag{C.32}$$

Substituting the log-linear approximation for $r_{s,t+1}$ from equation (C.30) and the nominal SDF from equation (C.27) into (C.31), we obtain the solutions for the coefficients $A_{0,s}$, $A_{1,s}$, and $A_{2,s}$:

$$\begin{aligned}
A_{1,s} &= \frac{\lambda\phi_s - \frac{1}{\psi}}{1 - \kappa_{1,s}\rho}, \\
A_{2,s,c} &= \frac{1}{1 - \kappa_{1,s}\nu_c} \left[(\theta - 1)A_2\left(\kappa_1\nu_c - 1\right) + \frac{1}{2}\left(\lambda\pi_s - \gamma\right)^2 + \frac{1}{2}\left(\kappa_{1,s}A_{1,s} + (\theta-1)\kappa_1 A_1\right)^2(1-\rho^2)\varphi_x^2\right] \\
A_{2,s,s} &= \frac{\frac{1}{2}\lambda^2}{1 - \kappa_{1,s}\nu_s}, \\
A_{0,s} &= \frac{1}{1 - \kappa_{1,s}} [\theta\log\delta - \gamma\mu_c + \kappa_{0,s} + \lambda\mu_s - \bar{\pi} \\
&\quad + (\theta - 1)\left(\kappa_0 + A_0\left(\kappa_1 - 1\right) + \kappa_1 A_2\left(1 - \nu_c\right)\left(\varphi_c\sigma\right)^2\right) \\
&\quad + \kappa_{1,s}A_{2,s,c}\left(1 - \nu_c\right)\left(\varphi_c\sigma\right)^2 + \kappa_{1,s}A_{2,s,s}\left(1 - \nu_s\right)\left(\varphi_s\sigma\right)^2 \\
&\quad + \frac{1}{2}\left(\kappa_{1,s}A_{2,s,s}\right)^2\sigma_{\omega_s}^2 + \frac{1}{2}\left(\kappa_{1,s}A_{2,s,c}(\theta-1) + \kappa_1 A_2\right)^2\sigma_{\omega_c}^2\Big]
\end{aligned} \tag{C.33}$$

Similarly, to determine the coefficients $\kappa_{1,s}$ and $\kappa_{0,s}$ we solved numerically for $\bar{pd}_s$ from the following system of equations:

$$\begin{aligned}
\bar{pd}_s &= A_{0,s}\left(\bar{pd}_s\right) + A_{2,s,c}\left(\bar{pd}_s\right)\left(\varphi_c\sigma\right)^2 + A_{2,s,s}\left(\bar{pd}_s\right)\left(\varphi_s\sigma\right)^2, \\
\kappa_{1,s} &= \frac{\exp(\bar{pd}_s)}{1+\exp(\bar{pd}_s)}, \\
\kappa_{0,s} &= \log(1+\exp(\bar{pd}_s)) - \kappa_{1,s}\bar{pd}_s.
\end{aligned}$$

Next, we rewrite the software-return from equation (C.30) as follows:

$$r_{s,t+1} - \mathbb{E}_t\left[r_{s,t+1}\right] = \beta_{s,c}\sigma_{c,t}\eta_{c,t+1} + \beta_{s,x}\sigma_{c,t}\eta_{x,t+1} + \beta_{s,s}\sigma_{s,t}\epsilon_{s,t+1} + \beta_{s,\omega_c}\sigma_{\omega_c}\omega_{c,t+1} + \beta_{s,\omega_s}\sigma_{\omega_s}\omega_{s,t+1} \tag{C.34}$$

where the βs are given by:

$$\beta_{s,c} = \lambda\pi_s, \quad \beta_{s,x} = \kappa_{1,s}A_{1,s}\sqrt{1-\rho^2}\varphi_x, \qquad \beta_{s,s} = \lambda, \quad \beta_{s,\omega_c} = \kappa_{1,s}A_{2,s,c}, \qquad \beta_{s,\omega_s} = \kappa_{1,s}A_{2,s,s}.$$

The risk premium for the software claim is

$$\begin{aligned}
\mathbb{E}_t\left(r_{s,t+1} - r_{f,t}\right) + \frac{1}{2}\operatorname{Var}_t\left(r_{s,t+1}\right) &= -\operatorname{Cov}_t\left(m^{\$}_{t+1}, r_{s,t+1}\right) \\
&= \beta_{s,\omega_c}\lambda_{\omega_c}\sigma^2_{\omega_c} + \left(\beta_{s,c}\lambda_c + \beta_{s,x}\lambda_x\right)\sigma^2_{c,t}
\end{aligned} \tag{C.35}$$

Finally, adjusting for the Jensen's terms, we obtain an expression for the ex ante expected excess returns:

$$\begin{aligned}
\mathbb{E}_t\left(r_{s,t+1} - r_{f,t}\right) = &\left(\beta_{s,c}\lambda_c + \beta_{s,x}\lambda_x - \frac{1}{2}\beta^2_{s,c} - \frac{1}{2}\beta^2_{s,x}\right)\sigma^2_{c,t} + \left(\beta_{s,\omega_c}\lambda_{\omega_c} - \frac{1}{2}\beta^2_{s,\omega_c}\right)\sigma^2_{\omega_c} \\
&- \frac{1}{2}\beta^2_{s,s}\sigma^2_{s,t} - \frac{1}{2}\beta^2_{s,\omega_s}\sigma^2_{\omega_s}
\end{aligned} \tag{C.36}$$

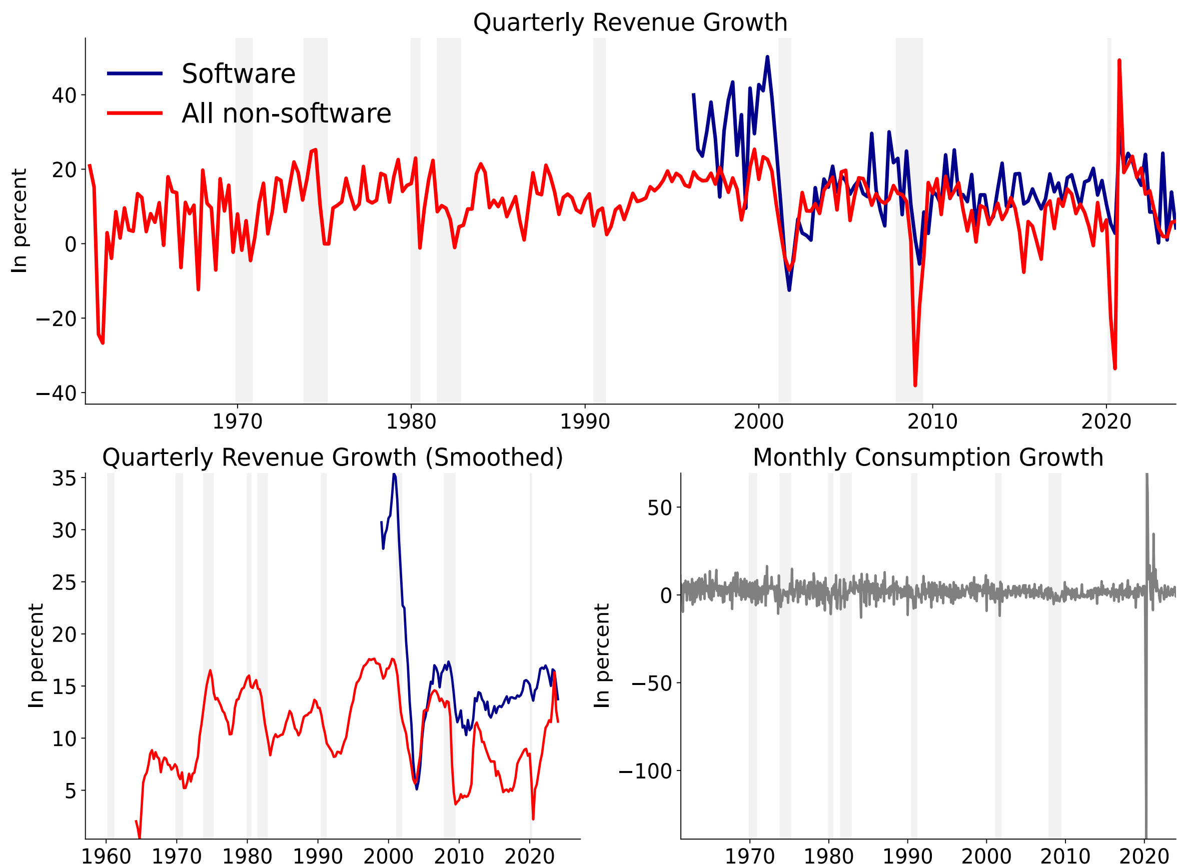
The ex post excess returns, $r_{s,t+1} - r_{f,t}$, are calculated by subtracting the risk-free rate in equation (C.28) from the return equation in (C.30). We define the α as the difference between the sample average of the ex post excess returns and the ex ante expected excess returns, where the sample average is denoted by the expectations operator with a T subscript, $\mathbb{E}_T$:

$$\alpha = \mathbb{E}_T\left[r_{s,t+1} - r_{f,t}\right] - \mathbb{E}_T\left[\mathbb{E}_t\left(r_{s,t+1} - r_{f,t}\right)\right]. \tag{C.37}$$

In the model section, we present results for $\mathbb{E}_T\left[r_{s,t+1} - r_{f,t}\right]$, $\mathbb{E}_T\left[\mathbb{E}_t\left(r_{s,t+1} - r_{f,t}\right)\right]$, and α.

C.6 Supplementary figures and tables

Fig. C.1. **Realized Growth Rates**



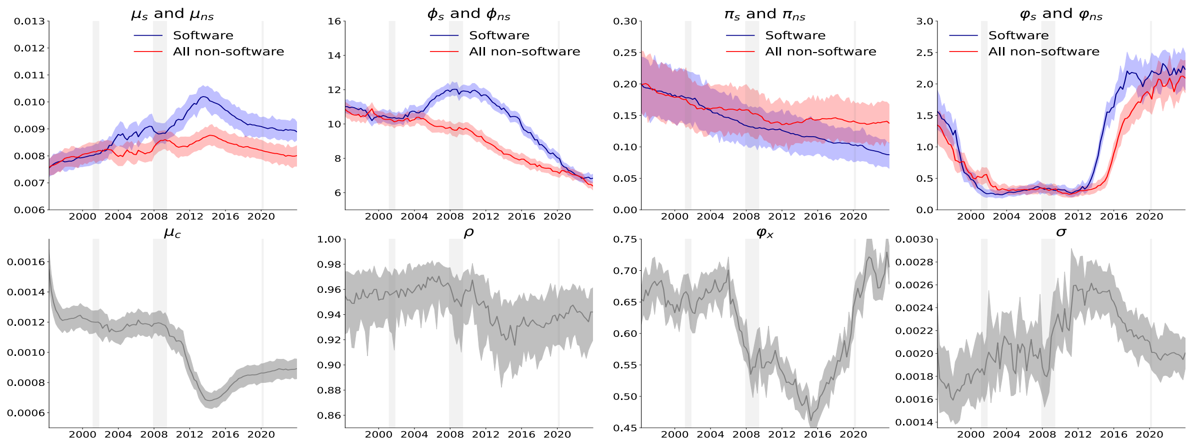
Notes: The top panel displays the quarterly revenue growth series for software and non-software companies from 1959Q4 to 2023Q4. To highlight the low-frequency trends, the lower left panel presents these series smoothed using a 3-year rolling window. The lower right panel depicts the real per capita consumption growth series, which is available at a monthly frequency. To facilitate comparison, we annualize the quarterly series and present them in percent by multiplying by 400, while we annualize the monthly series and present them in percent by multiplying by 1200.

Table C.1. **Initial Belief Distribution in 1996Q1**

Parameter	Distribution	Prior		
		1%	50%	99%
		Consumption growth process		
$\mu_c \times 100\%$	$\mathcal{N}$	0.16	0.18	0.19
ρ	$\mathcal{N}^T$	0.87	0.94	1.00
φ_x	$\mathcal{N}$	0.60	0.65	0.70
$\sigma \times 100\%$	$\mathcal{IG}$	0.19	0.28	0.43
ρ_{h_c}	$\mathcal{N}^T$	0.74	0.97	1.00
$\sigma^2_{h_c} \times 100\%$	$\mathcal{IG}$	0.09	0.30	1.97
		Non-software growth process		
$\mu_{ns} \times 100\%$	$\mathcal{N}$	0.71	0.75	0.78
ϕ_{ns}	$\mathcal{N}$	10.48	11.00	11.53
π_{ns}	$\mathcal{N}$	0.15	0.20	0.25
φ_{ns}	$\mathcal{N}$	1.16	1.50	1.84
$\rho_{h_{ns}}$	$\mathcal{N}^T$	0.73	0.97	1.00
$\sigma^2_{h_{ns}} \times 100\%$	$\mathcal{IG}$	0.09	0.30	1.97
		Software growth process		
$\mu_s \times 100\%$	$\mathcal{N}$	0.72	0.75	0.78
ϕ_s	$\mathcal{N}$	10.50	11.01	11.52
π_s	$\mathcal{N}$	0.15	0.20	0.25
φ_s	$\mathcal{N}$	1.15	1.50	1.85
ρ_{h_s}	$\mathcal{N}^T$	0.73	0.97	1.00
$\sigma^2_{h_s} \times 100\%$	$\mathcal{IG}$	0.09	0.30	1.98
		Consumption measurement error		
$\sigma_\epsilon \times 100\%$	$\mathcal{IG}$	0.12	0.17	0.27
$\sigma^q_\epsilon \times 100\%$	$\mathcal{IG}$	0.06	0.09	0.15

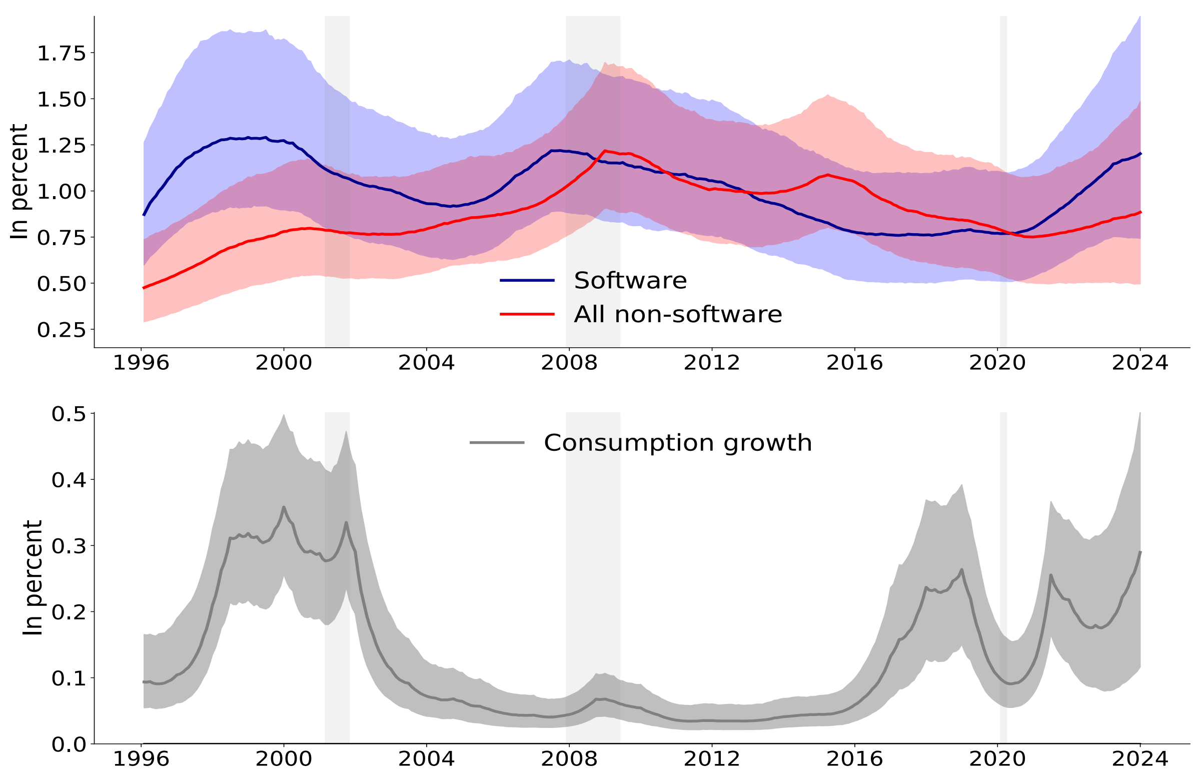
Notes: This table presents the initial belief distribution assumed 1996:Q1. $\mathcal{N}$, $\mathcal{N}^T$, and $\mathcal{IG}$ are normal, truncated (outside of the interval $(-1,1)$) normal, and inverse gamma distributions, respectively.

Fig. C.2. **Evolution of the Parameter Estimates**



Notes: The figure shows the evolution of the posterior median estimates along with the 98% confidence intervals between 1996Q1 and 2023Q4.

Fig. C.3. **Stochastic Volatility Estimates**



Notes: This figure shows the stochastic volatility estimates for software ($\sigma_{s,t}$), non-software ($\sigma_{ns,t}$), and consumption growth ($\sigma_{c,t}$), along with the 90% confidence intervals. NBER recession dates are indicated by gray shaded bars. The figure spans the period from January 1996 to December 2023.

Table C.2. **One-Period P-Values of Updated Beliefs Given Priors**

	5-year snapshots								
Parameter	1996	2000	2005	2015	2020	2023	min	mean	max
			Consumption growth process						
μ_c	1.00	0.54	0.64	0.39	0.50	0.46	0.20	0.54	1.00
ρ	0.31	0.46	0.47	0.60	0.42	0.51	0.30	0.47	0.65
φ_x	0.36	0.27	0.43	0.89	0.25	0.28	0.02	0.48	0.99
σ	0.96	0.34	0.18	0.43	0.52	0.43	0.17	0.43	0.96
ρ_{h_c}	0.39	0.49	0.50	0.50	0.50	0.50	0.39	0.50	0.51
$\sigma^2_{h_c}$	0.12	0.37	0.41	0.36	0.35	0.36	0.12	0.36	0.49
			Non-software growth process						
μ_{ns}	0.31	0.45	0.70	0.62	0.57	0.52	0.16	0.49	0.71
ϕ_{ns}	0.74	0.51	0.64	0.69	0.73	0.87	0.12	0.59	0.91
π_{ns}	0.53	0.49	0.52	0.46	0.55	0.47	0.42	0.51	0.64
φ_{ns}	0.85	0.89	0.41	0.07	0.67	0.41	0.02	0.48	0.96
$\rho_{h_{ns}}$	0.39	0.50	0.50	0.50	0.50	0.50	0.39	0.50	0.53
$\sigma^2_{h_{ns}}$	0.43	0.32	0.29	0.28	0.34	0.41	0.01	0.38	1.00
			Software growth process						
μ_s	0.35	0.46	0.24	0.57	0.55	0.47	0.16	0.47	0.86
ϕ_s	0.48	0.57	0.19	0.50	0.65	0.41	0.10	0.57	0.99
π_s	0.50	0.57	0.52	0.51	0.47	0.57	0.45	0.53	0.64
φ_s	0.35	0.59	0.37	0.13	0.36	0.34	0.01	0.48	0.98
ρ_{h_s}	0.39	0.51	0.51	0.50	0.50	0.51	0.39	0.50	0.53
$\sigma^2_{h_s}$	0.43	0.32	0.29	0.28	0.34	0.40	0.01	0.38	1.00
			Consumption measurement error						
σ_ϵ	0.20	0.35	0.50	0.41	0.36	0.36	0.20	0.43	0.65
σ^q_ϵ	0.00	0.62	0.91	0.40	0.51	0.41	0.00	0.45	0.93

Notes: This table presents the one-period p-values for each model parameter in Θ, given the corresponding prior at time t. To compute these p-values, we simulated draws from the time t prior distribution of each parameter in Θ and calculated the percentage of these draws that exceed the posterior median at time $t+1$. Columns 1 through 6 provide 5-year snapshots of these one-period p-values. The last three columns report the minimum, mean, and maximum values of these p-values over the entire sample period.

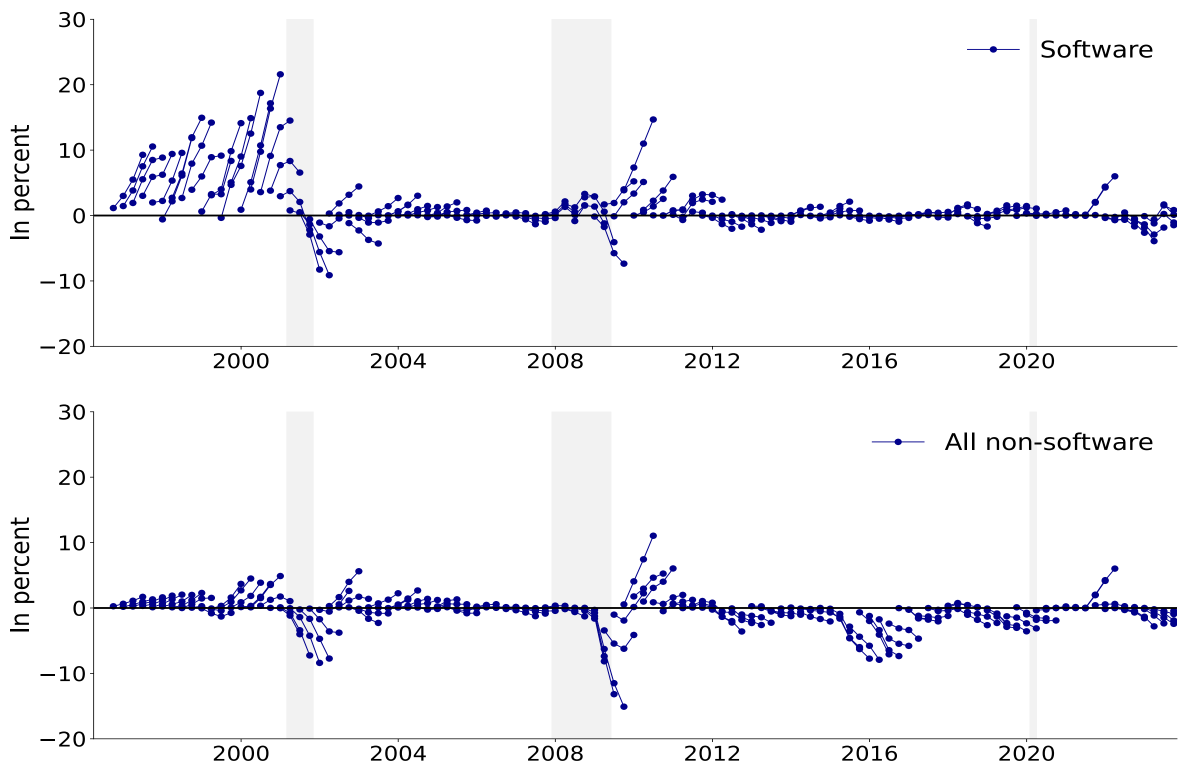
C.7 *Alternative initial beliefs*

This section presents results for three alternative assumptions about agents' initial beliefs in our model.

Section C.7.1 examines agents with more dispersed initial beliefs about Θ. We center the 1996 median beliefs about software around non-software beliefs, but allow a wider distribution of initial beliefs, though not wide enough to encompass the 2023 posterior median values. Section C.7.2 extends this approach, centering beliefs similarly but allowing an even wider distribution that does encompass the 2023 posterior median values. Finally, Section C.7.3 directly sets the initial beliefs in 1996 equal to the posterior median estimates in 2023, effectively endowing agents with perfect foresight about the end-of-sample parameters.

C.7.1 *Loose initial beliefs*

Fig. C.4. **Biases in Model-Implied Forecasts: Loose Initial Beliefs**



Notes: This figure shows the average model-implied forecast bias for every quarter in our sample for software companies, and all non-software companies. Each line in the figure represents the model-implied average forecast error across simulations for the current quarter and the subsequent three quarters. NBER recession dates are indicated by gray shaded bars.

Table C.3. **Initial Belief Distribution in 1996Q1: Loose Initial Beliefs**

Parameter	Distribution	Prior		
		1%	50%	99%
		Consumption growth process		
$\mu_c \times 100\%$	$\mathcal{N}$	0.16	0.18	0.19
ρ	$\mathcal{N}^T$	0.87	0.94	1.00
φ_x	$\mathcal{N}$	0.60	0.65	0.70
$\sigma \times 100\%$	$\mathcal{IG}$	0.19	0.28	0.43
ρ_{h_c}	$\mathcal{N}^T$	0.74	0.97	1.00
$\sigma_{h_c}^2 \times 100\%$	$\mathcal{IG}$	0.09	0.30	1.97
		Non-software growth process		
$\mu_{ns} \times 100\%$	$\mathcal{N}$	0.69	0.75	0.81
ϕ_{ns}	$\mathcal{N}$	10.14	11.00	11.88
π_{ns}	$\mathcal{N}$	0.15	0.20	0.25
φ_{ns}	$\mathcal{N}$	1.16	1.50	1.84
$\rho_{h_{ns}}$	$\mathcal{N}^T$	0.73	0.97	1.00
$\sigma_{h_{ns}}^2 \times 100\%$	$\mathcal{IG}$	0.09	0.30	1.97
		Software growth process		
$\mu_s \times 100\%$	$\mathcal{N}$	0.69	0.75	0.81
ϕ_s	$\mathcal{N}$	10.16	11.01	11.86
π_s	$\mathcal{N}$	0.15	0.20	0.25
φ_s	$\mathcal{N}$	1.15	1.50	1.85
ρ_{h_s}	$\mathcal{N}^T$	0.73	0.97	1.00
$\sigma_{h_s}^2 \times 100\%$	$\mathcal{IG}$	0.09	0.30	1.98
		Consumption measurement error		
$\sigma_\epsilon \times 100\%$	$\mathcal{IG}$	0.12	0.17	0.27
$\sigma_\epsilon^q \times 100\%$	$\mathcal{IG}$	0.06	0.09	0.15

Notes: This table presents the initial belief distribution assumed 1996:Q1. $\mathcal{N}$, $\mathcal{N}^T$, and $\mathcal{IG}$ are normal, truncated (outside of the interval $(-1, 1)$) normal, and inverse gamma distributions, respectively.

Table C.4. **Forecast Anomalies: Loose Initial Beliefs**

	Software Forecast horizon in quarters				Non-software Forecast horizon in quarters			
	1	2	3	4	1	2	3	4
A. Bias								
Model	0.46	1.05	1.63	2.19	-0.17	-0.40	-0.63	-0.89
	[1.78]	[1.75]	[1.72]	[1.67]	[-1.64]	[-1.64]	[-1.58]	[-1.53]
Data consensus	2.21	1.78	2.21	2.94	1.54	0.03	-1.41	-2.25
	[6.88]	[2.69]	[2.16]	[2.06]	[7.15]	[0.08]	[-2.36]	[-2.98]
Data individual	2.70	2.52	2.79	3.18	1.32	0.35	-0.01	0.11
	[13.69]	[5.99]	[4.34]	[3.98]	[7.42]	[0.83]	[-0.02]	[0.15]
B. Autocorrelation								
Model	0.31	0.60	0.42	0.37	0.43	0.27	0.07	-0.09
	[2.03]	[5.44]	[2.15]	[1.54]	[6.35]	[2.07]	[0.32]	[-0.52]
Data consensus	0.39	0.21	0.08	0.04	0.09	0.08	0.07	0.08
	[3.09]	[4.10]	[3.10]	[1.36]	[6.58]	[5.56]	[4.60]	[4.76]
Data individual	0.32	0.23	0.17	0.12	0.26	0.21	0.18	0.13
	[5.79]	[6.90]	[5.46]	[2.92]	[15.44]	[11.40]	[7.01]	[4.90]
C. Mincer-Zarnowitz								
Model	1.13	1.11	1.05	0.98	1.06	1.00	0.93	0.82
	[0.61]	[0.44]	[0.20]	[-0.08]	[1.03]	[0.03]	[-0.74]	[-1.60]
Data consensus	0.98	0.92	0.91	0.88	0.86	0.85	0.83	0.81
	[-0.86]	[-2.37]	[-2.68]	[-1.73]	[-16.14]	[-14.69]	[-13.36]	[-8.66]
Data individual	0.97	0.92	0.95	1.01	0.83	0.82	0.82	0.78
	[-2.98]	[-3.77]	[-1.99]	[0.17]	[-16.52]	[-16.24]	[-15.66]	[-11.79]
D. Coibion-Gorodnichenko								
Model	-0.08	0.00	0.07		0.16	0.31	0.47	
	[-0.96]	[0.03]	[0.68]		[1.92]	[2.80]	[4.75]	
Data consensus	0.13	0.24	0.28		0.07	0.13	0.15	
	[8.37]	[7.65]	[6.22]		[6.07]	[5.23]	[6.04]	
Data individual	0.13	0.18	0.20		0.08	0.15	0.18	
	[6.62]	[4.38]	[4.09]		[5.95]	[4.00]	[4.58]	

Notes: This table presents four different tests of forecast rationality using model-implied forecasts, analyst consensus forecasts, and forecasts by individual analysts. The model-implied forecasts are derived using posterior median estimates. The t-statistics, presented in brackets, are relative to the following hypotheses: Bias = 0, Autocorrelation = 0, Mincer-Zarnowitz = 1, and Coibion-Gorodnichenko = 0. For the model-implied moments, Newey-West standard errors are used with the lag length selected as $L = \lceil 1.3 \times T^{1/2} \rceil$. For the data moments, standard errors are clustered by both firm and date. The forecast horizons are in quarters, and the forecast errors and forecast revisions used in the tests are expressed in percent. The sample spans from 1996Q1 to 2023Q3.

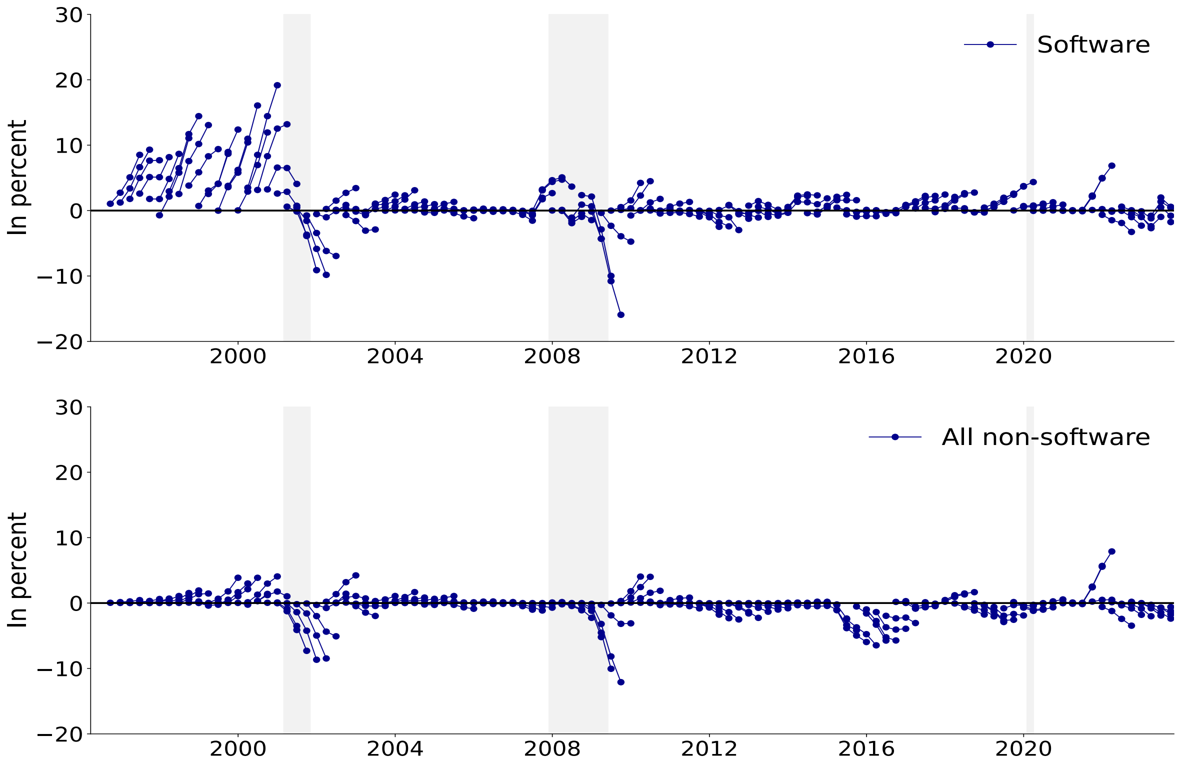
Table C.5. **Performance Evaluation and Alphas: Loose Initial Beliefs**

	Software			Non-software		
	Data			Data		
Name	EW	VW	Model	EW	VW	Model
$E_T\left(r_{i,t+1}\right)$	18.54	15.67	7.95	10.93	9.95	4.50
$E_T\left(r_{i,t+1}-r_{f,t}\right)$	16.44	13.57	6.06	8.83	7.86	2.61
$E_T\left(\mathbb{E}_t\left(r_{i,t+1}-r_{f,t}\right)\right)$	10.73	9.31	4.07	9.27	8.44	4.02
α	5.71	4.27	1.99	-0.44	-0.58	-1.41

Notes: This table reports asset pricing moments from the data and as implied by the model for both software and non-software companies. We report average ex post returns, $E_T\left(r_{i,t+1}\right)$, average ex post excess returns, $E_T\left(r_{i,t+1}-r_{f,t}\right)$, average ex ante excess returns, $E_T\left(\mathbb{E}_t\left(r_{i,t+1}-r_{f,t}\right)\right)$, and alphas, α, where E_T denotes the sample average. For the data moments, we report these values using both equally-weighted (EW) and value-weighted portfolios (VW). To compute the average ex ante excess returns and alphas, we employ the Fama-French three-factor model. For the model-implied moments, we use the posterior median estimates and fix the preference parameters to $\gamma = 10$, $\beta = 0.999$, and $\psi = 1.5$. In both the model and the data, the frequency is monthly, and we report annualized values.

C.7.2 Very Loose initial beliefs

Fig. C.5. **Biases in Model-implied Forecasts: Very Loose Initial Beliefs**



Notes: This figure shows the average model-implied forecast bias for every quarter in our sample for software companies, and all non-software companies. Each line in the figure represents the model-implied average forecast error across simulations for the current quarter and the subsequent three quarters. NBER recession dates are indicated by gray shaded bars.

Table C.6. **Initial Belief Distribution in 1996Q1: Very Loose Initial Beliefs**

		Prior		
Parameter	Distribution	1%	50%	99%
		Consumption growth process		
$\mu_c \times 100\%$	$\mathcal{N}$	0.16	0.18	0.19
ρ	$\mathcal{N}^T$	0.87	0.94	1.00
φ_x	$\mathcal{N}$	0.60	0.65	0.70
$\sigma \times 100\%$	$\mathcal{IG}$	0.19	0.28	0.43
ρ_{h_c}	$\mathcal{N}^T$	0.74	0.97	1.00
$\sigma^2_{h_c} \times 100\%$	$\mathcal{IG}$	0.09	0.30	1.97
		Non-software growth process		
$\mu_{ns} \times 100\%$	$\mathcal{N}$	0.58	0.75	0.93
ϕ_{ns}	$\mathcal{N}$	5.84	11.01	16.26
π_{ns}	$\mathcal{N}$	0.04	0.20	0.36
φ_{ns}	$\mathcal{N}$	0.37	1.49	2.64
$\rho_{h_{ns}}$	$\mathcal{N}^T$	0.73	0.97	1.00
$\sigma^2_{h_{ns}} \times 100\%$	$\mathcal{IG}$	0.09	0.30	1.97
		Software growth process		
$\mu_s \times 100\%$	$\mathcal{N}$	0.58	0.75	0.92
ϕ_s	$\mathcal{N}$	5.96	11.05	16.18
π_s	$\mathcal{N}$	0.04	0.20	0.35
φ_s	$\mathcal{N}$	0.34	1.51	2.65
ρ_{h_s}	$\mathcal{N}^T$	0.73	0.97	1.00
$\sigma^2_{h_s} \times 100\%$	$\mathcal{IG}$	0.09	0.30	1.98
		Consumption measurement error		
$\sigma_\epsilon \times 100\%$	$\mathcal{IG}$	0.12	0.17	0.27
$\sigma^q_\epsilon \times 100\%$	$\mathcal{IG}$	0.06	0.09	0.15

Notes: This table presents the initial belief distribution assumed 1996:Q1. $\mathcal{N}$, $\mathcal{N}^T$, and $\mathcal{IG}$ are normal, truncated (outside of the interval $(-1, 1)$) normal, and inverse gamma distributions, respectively.

Table C.7. **Forecast Anomalies: Very Loose Initial Beliefs**

	Software				Non-software			
	Forecast horizon in quarters				Forecast horizon in quarters			
	1	2	3	4	1	2	3	4
A. Bias								
Model	0.40	0.88	1.32	1.72	-0.14	-0.34	-0.57	-0.83
	[1.80]	[1.71]	[1.57]	[1.43]	[-1.94]	[-2.15]	[-2.16]	[-2.02]
Data consensus	2.21	1.78	2.21	2.94	1.54	0.03	-1.41	-2.25
	[6.88]	[2.69]	[2.16]	[2.06]	[7.15]	[0.08]	[-2.36]	[-2.98]
Data individual	2.70	2.52	2.79	3.18	1.32	0.35	-0.01	0.11
	[13.69]	[5.99]	[4.34]	[3.98]	[7.42]	[0.83]	[-0.02]	[0.15]
B. Autocorrelation								
Model	0.29	0.44	0.37	0.28	0.47	0.28	0.06	-0.10
	[2.43]	[2.66]	[2.04]	[1.20]	[4.39]	[2.45]	[0.42]	[-0.90]
Data consensus	0.39	0.21	0.08	0.04	0.09	0.08	0.07	0.08
	[3.09]	[4.10]	[3.10]	[1.36]	[6.58]	[5.56]	[4.60]	[4.76]
Data individual	0.32	0.23	0.17	0.12	0.26	0.21	0.18	0.13
	[5.79]	[6.90]	[5.46]	[2.92]	[15.44]	[11.40]	[7.01]	[4.90]
C. Mincer-Zarnowitz								
Model	1.22	1.26	1.23	1.18	1.04	1.04	1.01	0.94
	[1.97]	[1.67]	[1.32]	[0.91]	[1.30]	[0.94]	[0.14]	[-0.67]
Data consensus	0.98	0.92	0.91	0.88	0.86	0.85	0.83	0.81
	[-0.86]	[-2.37]	[-2.68]	[-1.73]	[-16.14]	[-14.69]	[-13.36]	[-8.66]
Data individual	0.97	0.92	0.95	1.01	0.83	0.82	0.82	0.78
	[-2.98]	[-3.77]	[-1.99]	[0.17]	[-16.52]	[-16.24]	[-15.66]	[-11.79]
D. Coibion-Gorodnichenko								
Model	-0.13	0.00	0.15		0.02	0.12	0.27	
	[-1.42]	[0.06]	[2.03]		[0.72]	[2.40]	[3.66]	
Data consensus	0.13	0.24	0.28		0.07	0.13	0.15	
	[8.37]	[7.65]	[6.22]		[6.07]	[5.23]	[6.04]	
Data individual	0.13	0.18	0.20		0.08	0.15	0.18	
	[6.62]	[4.38]	[4.09]		[5.95]	[4.00]	[4.58]	

Notes: This table presents four different tests of forecast rationality using model-implied forecasts, analyst consensus forecasts, and forecasts by individual analysts. The model-implied forecasts are derived using posterior median estimates. The t-statistics, presented in brackets, are relative to the following hypotheses: Bias = 0, Autocorrelation = 0, Mincer-Zarnowitz = 1, and Coibion-Gorodnichenko = 0. For the model-implied moments, Newey-West standard errors are used with the lag length selected as $L = \lceil 1.3 \times T^{1/2} \rceil$. For the data moments, standard errors are clustered by both firm and date. The forecast horizons are in quarters, and the forecast errors and forecast revisions used in the tests are expressed in percent. The sample spans from 1996Q1 to 2023Q3.

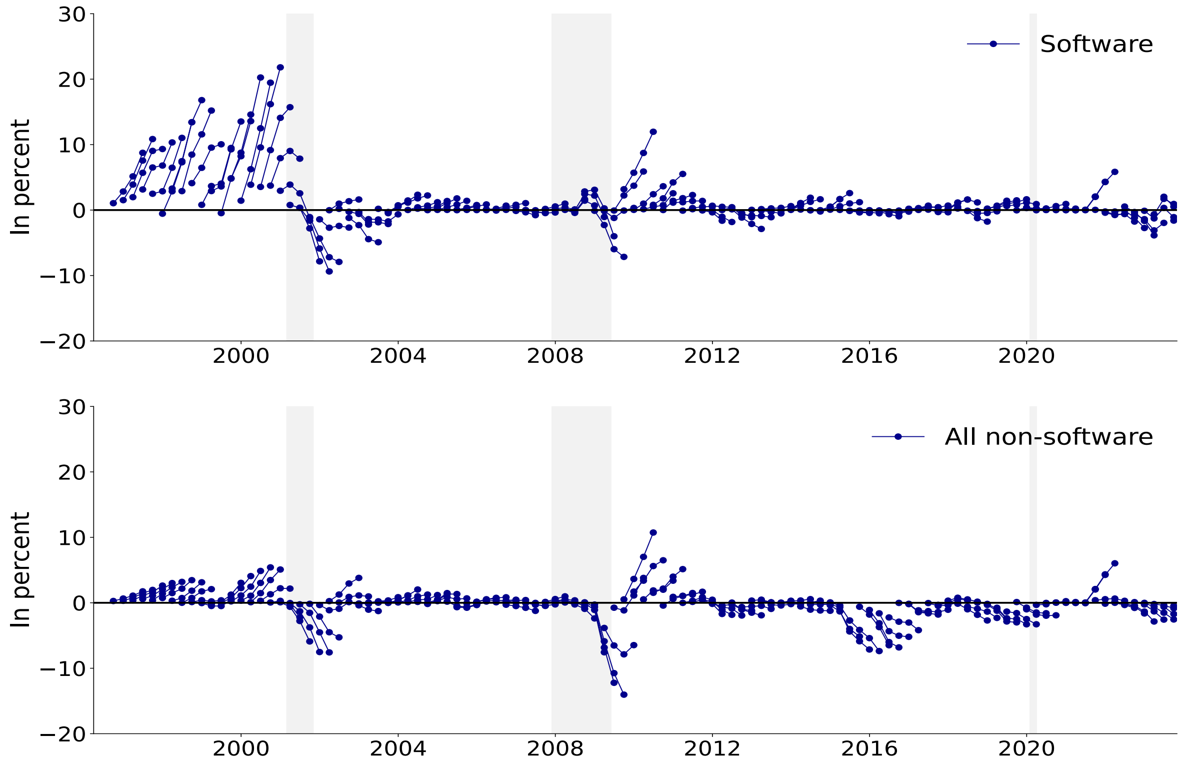
Table C.8. **Performance Evaluation and Alphas: Very Loose Initial Beliefs**

	Software			Non-software		
	Data			Data		
Name	EW	VW	Model	EW	VW	Model
$E_T\left(r_{i,t+1}\right)$	18.54	15.67	5.17	10.93	9.95	2.45
$E_T\left(r_{i,t+1} - r_{f,t}\right)$	16.44	13.57	3.22	8.83	7.86	0.50
$E_T\left(\mathbb{E}_t\left(r_{i,t+1} - r_{f,t}\right)\right)$	10.73	9.31	3.63	9.27	8.44	3.75
α	5.71	4.27	-0.41	-0.44	-0.58	-3.25

Notes: This table reports asset pricing moments from the data and as implied by the model for both software and non-software companies. We report average ex post returns, $E_T\left(r_{i,t+1}\right)$, average ex post excess returns, $E_T\left(r_{i,t+1} - r_{f,t}\right)$, average ex ante excess returns, $E_T\left(\mathbb{E}_t\left(r_{i,t+1} - r_{f,t}\right)\right)$, and alphas, α, where E_T denotes the sample average. For the data moments, we report these values using both equally-weighted (EW) and value-weighted portfolios (VW). To compute the average ex ante excess returns and alphas, we employ the Fama-French three-factor model. For the model-implied moments, we use the posterior median estimates and fix the preference parameters to $\gamma = 10$, $\beta = 0.999$, and $\psi = 1.5$. In both the model and the data, the frequency is monthly, and we report annualized values.

C.7.3 Look-ahead initial beliefs

Fig. C.6. **Biases in Model-implied Forecasts: Look-Ahead Initial Beliefs**



Notes: This figure shows the average model-implied forecast bias for every quarter in our sample for software companies, and all non-software companies. Each line in the figure represents the model-implied average forecast error across simulations for the current quarter and the subsequent three quarters. NBER recession dates are indicated by gray shaded bars.

Table C.9. **Initial Belief Distribution in 1996Q1: Look-Ahead Initial Beliefs**

Parameter	Distribution	Prior		
		1%	50%	99%
	Consumption growth process			
$\mu_c \times 100\%$	$\mathcal{N}$	0.08	0.09	0.10
ρ	$\mathcal{N}^T$	0.87	0.94	1.00
φ_x	$\mathcal{N}$	0.65	0.71	0.76
$\sigma \times 100\%$	$\mathcal{IG}$	0.13	0.19	0.30
ρ_{h_c}	$\mathcal{N}^T$	0.76	0.99	1.00
$\sigma^2_{h_c} \times 100\%$	$\mathcal{IG}$	0.38	1.26	8.35
	Non-software growth process			
$\mu_{ns} \times 100\%$	$\mathcal{N}$	0.76	0.80	0.84
ϕ_{ns}	$\mathcal{N}$	6.09	6.39	6.69
π_{ns}	$\mathcal{N}$	0.11	0.14	0.17
φ_{ns}	$\mathcal{N}$	1.62	2.09	2.57
$\rho_{h_{ns}}$	$\mathcal{N}^T$	0.76	1.00	1.00
$\sigma^2_{h_{ns}} \times 100\%$	$\mathcal{IG}$	0.08	0.26	1.74
	Software growth process			
$\mu_s \times 100\%$	$\mathcal{N}$	0.85	0.89	0.93
ϕ_s	$\mathcal{N}$	6.53	6.84	7.16
π_s	$\mathcal{N}$	0.07	0.09	0.11
φ_s	$\mathcal{N}$	1.71	2.23	2.74
ρ_{h_s}	$\mathcal{N}^T$	0.76	1.00	1.00
$\sigma^2_{h_s} \times 100\%$	$\mathcal{IG}$	0.08	0.26	1.75
	Consumption measurement error			
$\sigma_\epsilon \times 100\%$	$\mathcal{IG}$	0.09	0.13	0.20
$\sigma^q_\epsilon \times 100\%$	$\mathcal{IG}$	0.07	0.10	0.17

Notes: This table presents the initial belief distribution assumed 1996:Q1. $\mathcal{N}$, $\mathcal{N}^T$, and $\mathcal{IG}$ are normal, truncated (outside of the interval $(-1, 1)$) normal, and inverse gamma distributions, respectively.

Table C.10. **Forecast Anomalies: Look-Ahead Initial Beliefs**

	Software				Non-software			
	Forecast horizon in quarters				Forecast horizon in quarters			
	1	2	3	4	1	2	3	4
A. Bias								
Model	0.42	0.99	1.59	2.19	-0.13	-0.29	-0.42	-0.56
	[1.57]	[1.56]	[1.55]	[1.54]	[-1.28]	[-1.18]	[-1.05]	[-0.96]
Data consensus	2.21	1.78	2.21	2.94	1.54	0.03	-1.41	-2.25
	[6.88]	[2.69]	[2.16]	[2.06]	[7.15]	[0.08]	[-2.36]	[-2.98]
Data individual	2.70	2.52	2.79	3.18	1.32	0.35	-0.01	0.11
	[13.69]	[5.99]	[4.34]	[3.98]	[7.42]	[0.83]	[-0.02]	[0.15]
B. Autocorrelation								
Model	0.41	0.59	0.50	0.41	0.37	0.27	0.10	-0.08
	[3.81]	[4.27]	[2.84]	[1.76]	[4.14]	[1.79]	[0.51]	[-0.45]
Data consensus	0.39	0.21	0.08	0.04	0.09	0.08	0.07	0.08
	[3.09]	[4.10]	[3.10]	[1.36]	[6.58]	[5.56]	[4.60]	[4.76]
Data individual	0.32	0.23	0.17	0.12	0.26	0.21	0.18	0.13
	[5.79]	[6.90]	[5.46]	[2.92]	[15.44]	[11.40]	[7.01]	[4.90]
C. Mincer-Zarnowitz								
Model	1.24	1.24	1.17	1.08	1.05	1.02	0.95	0.85
	[1.17]	[0.86]	[0.59]	[0.29]	[0.94]	[0.23]	[-0.40]	[-1.12]
Data consensus	0.98	0.92	0.91	0.88	0.86	0.85	0.83	0.81
	[-0.86]	[-2.37]	[-2.68]	[-1.73]	[-16.14]	[-14.69]	[-13.36]	[-8.66]
Data individual	0.97	0.92	0.95	1.01	0.83	0.82	0.82	0.78
	[-2.98]	[-3.77]	[-1.99]	[0.17]	[-16.52]	[-16.24]	[-15.66]	[-11.79]
D. Coibion-Gorodnichenko								
Model	-0.04	0.16	0.31		0.16	0.40	0.61	
	[-0.40]	[1.90]	[1.83]		[2.30]	[2.94]	[4.31]	
Data consensus	0.13	0.24	0.28		0.07	0.13	0.15	
	[8.37]	[7.65]	[6.22]		[6.07]	[5.23]	[6.04]	
Data individual	0.13	0.18	0.20		0.08	0.15	0.18	
	[6.62]	[4.38]	[4.09]		[5.95]	[4.00]	[4.58]	

Notes: This table presents four different tests of forecast rationality using model-implied forecasts, analyst consensus forecasts, and forecasts by individual analysts. The model-implied forecasts are derived using posterior median estimates. The t-statistics, presented in brackets, are relative to the following hypotheses: Bias = 0, Autocorrelation = 0, Mincer-Zarnowitz = 1, and Coibion-Gorodnichenko = 0. For the model-implied moments, Newey-West standard errors are used with the lag length selected as $L = \lceil 1.3 \times T^{1/2} \rceil$. For the data moments, standard errors are clustered by both firm and date. The forecast horizons are in quarters, and the forecast errors and forecast revisions used in the tests are expressed in percent. The sample spans from 1996Q1 to 2023Q3.

Table C.11. **Performance Evaluation and Alphas: Look-Ahead Initial Beliefs**

	Software			Non-software		
	Data			Data		
Name	EW	VW	Model	EW	VW	Model
$E_T\left(r_{i,t+1}\right)$	18.54	15.67	9.08	10.93	9.95	5.63
$E_T\left(r_{i,t+1} - r_{f,t}\right)$	16.44	13.57	7.33	8.83	7.86	3.87
$E_T\left(\mathbb{E}_t\left(r_{i,t+1} - r_{f,t}\right)\right)$	10.73	9.31	5.34	9.27	8.44	5.09
α	5.71	4.27	1.98	-0.44	-0.58	-1.22

Notes: This table reports asset pricing moments from the data and as implied by the model for both software and non-software companies. We report average ex post returns, $E_T\left(r_{i,t+1}\right)$, average ex post excess returns, $E_T\left(r_{i,t+1} - r_{f,t}\right)$, average ex ante excess returns, $E_T\left(\mathbb{E}_t\left(r_{i,t+1} - r_{f,t}\right)\right)$, and alphas, α, where E_T denotes the sample average. For the data moments, we report these values using both equally-weighted (EW) and value-weighted portfolios (VW). To compute the average ex ante excess returns and alphas, we employ the Fama-French three-factor model. For the model-implied moments, we use the posterior median estimates and fix the preference parameters to $\gamma = 10$, $\beta = 0.999$, and $\psi = 1.5$. In both the model and the data, the frequency is monthly, and we report annualized values.