Capital (Mis)allocation,
Incentives and Productivity

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Abstract

This paper argues that managerial incentives affect capital misallocation within firms. We provide empirical evidence that firms reallocate capital towards less durable investment projects when managerial pay becomes more short-term oriented after a change in US accounting regulations. This reallocation of investment may raise within-firm capital misallocation. To rationalize and quantify this channel of within-firm misallocation, we develop a model of firm investment under agency frictions. A shift from equity compensation to profit-based bonus pay increases managers' focus on short-term profits, leading to underinvestment in low-depreciation assets, capital misallocation and lower productivity.

Keywords: Investment, Managerial Incentives, Capital Misallocation.

JEL: E22, G31, D24, D25, L23.

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1 Introduction

How do individuals react to monetary incentives, and what unintended consequences may emerge when incentives aim at short-term outcomes? We study this question in the context of capital allocation within firms. While a large literature has studied how ineffective allocations of capital across firms can reduce aggregate productivity,[1] we study how short-term incentives affect the allocation of capital within firms. These incentives often derive from performance-pay structures, encapsulating a blend of profit-linked cash bonuses and equity-based rewards. While cash bonuses incentivize short-term profit maximization, equity-based compensation may better align managers' incentives with maximizing long-term firm value. Therefore, such short-term incentivization might bias investment toward projects with quick but relatively short-lived returns (e.g., computer equipment or advertising) at the expense of more durable, long-term investments (e.g., production facilities). As a result, managerial incentives affect within-firm capital misallocation. In this paper, we quantify the effect of managerial incentives on investment, productivity, and the economy.

Our paper makes two contributions to the literature. First, we provide novel empirical evidence on the effects of the managerial pay structure on the allocation of capital within firms. We show that firms exposed to an accounting reform that shifted managerial compensation towards cash bonuses (i) invested relatively more in investment projects with high depreciation rates and their weighted average depreciation rate increased, (ii) their self-reported discount rates increased, and (iii) their productivity decreased. Second, we develop a quantitative model to rationalize the evidence and study its implications. In the model, a more generous cash bonus distorts the allocation of capital toward more short-lived investment projects. As a result, within-firm capital misallocation increases and firm productivity falls. While the reduction in firm productivity builds up gradually and is key for the long-run effects of the reform, the short-run effects are dominated by an immediate decline in total investment.

Our empirical analysis levers a quasi-natural experiment which provides a shift in managerial pay that is unrelated to economic fundamentals and incentive contracting problems within firms. The 2005 FAS 123R reform of accounting rules in the US raised the costs of equity-based compensation.[2]

[1] See e.g. Hsieh and Klenow (2009).

[2] Prior to the reform, equity options had an accounting advantage as firms were allowed to expense equity-linked

In response to the reform, firms lowered equity-based compensation and increased cash bonuses (Hayes et al. 2012). To assess whether the change in pay structure changed firm investment, we use balance sheet data for listed US firms from Compustat and FactSet which allow us to distinguish seven investment categories that differ in their depreciation rates.[3]

Our main empirical finding is that managers affected by the reform invest less in projects with low depreciation rates and relatively more in high-depreciation projects. The estimated effect is statistically significant, robust in various dimensions, and quantitatively meaningful. Managers exposed to the reform invest between 5 and 10% more in investment projects with a 10 percentage point higher depreciation rate relative to non-exposed managers. This shift towards short-term investment projects is also reflected in a 1 percentage-point increase in the weighted average depreciation rate. Consistent with more short-term incentives, the discount rate that managers use to evaluate new investment opportunities increases by 0.4 percentage points.[4] Importantly, exposed firms further experience a significant decline in productivity, consistent with the shift across investment types raising within-firm capital misallocation.

To rationalize the empirical findings and to study the implications of managerial pay, we develop and calibrate a model which extends the standard dynamic model of firm investment in two dimensions. First, we introduce a manager who faces monetary incentives from a compensation package that includes a cash bonus on current profits and equity compensation, similar to Nikolov and Whited (2014). Second, we introduce two types of capital that differ in their depreciation rates. Managers combine low-depreciation and high-depreciation capital with labor to produce output. In the model, the larger the share of firm equity owned by the manager the better her incentives align with value maximization. We show that if the compensation package includes a cash bonus, the rational manager's optimization problem mirrors an optimization problem under quasi-hyperbolic discounting. This implies time inconsistency and leads to investment short-termism which favors investment in the high-depreciation capital good.[5]

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compensation at its intrinsic value (Hayes et al. 2012). Abolishing this accounting advantage the reform raised the costs of equity options, which constitute a large fraction of equity-based compensation. See Frydman and Jenter (2010) and Murphy (1999) for empirical surveys on CEO compensation packages.

[3]Notably, we consider firm investment in land, buildings, machinery, transport equipment, R&D, computer equipment, and advertising. The associated depreciation rates are in descending order.

[4]We use recent data from Gormsen and Huber (2022), who measure the discount rate as the minimum required return on new investments as announced in earning calls.

[5]From a computational point of view, our model shares many similarities with models of quasi-hyperbolic discount-

We calibrate the model to match firm and sector-level moments of the US economy in a simulated sample of firms prior to the reform. We then simulate the effects of an unexpected exogenous change in the managerial pay structure that resembles the FAS 123R reform. The change in the managerial pay structure raises the present bias of managers. The present-bias factor in discounting falls by 3% on average. The response is a short-run drop in total investment. Importantly, the decline in investment is asymmetric across types of capital goods: investment in low-depreciation capital declines more, so that the intra-firm allocation of capital shifts to high-depreciation capital goods. This raises within-firm misallocation of capital, as managers internalize less of the benefits of long-lived investment projects. As a result, productivity declines. In general equilibrium, the accounting reform leads to a long-run decline in the real wage of 0.2%.

This paper relates to a growing literature that studies the effects of short-termism. Policy-makers, business executives and investors have often warned about the dangers of boosting short-term profits at the cost of long-term value (e.g., Dimon and Buffet 2018 or Barton 2011). Our paper is most closely related to Terry (2022), who studies the implications of managerial short-termism on R&D and growth. Instead, we study how managerial short-termism affects the allocation of investment across asset-durability types providing novel empirical evidence and a quantitative analysis. While Terry (2022) emphasizes the impact of short-termism on productivity through the neglect of positive R&D externalities, our study demonstrates that short-termism affects productivity by causing capital misallocation within firms. Our paper is thereby also related to a large literature studying factor misallocation (e.g., Hsieh and Klenow 2009, Alder 2016, Kehrig and Vincent 2019, Midrigan and Xu 2014, David and Venkateswaran 2019, Peters 2020, Meier and Reinelt forthcoming). However, while the prior literature studies capital misallocation across firms, we propose a novel mechanism for capital misallocation within firms.

Our model borrows from Bénabou and Tirole (2016) and Garicano and Rayo (2016) by formalizing managerial short-termism as a multitasking problem in which agents choose between short-term projects and long-term projects. We embed this idea into a dynamic model of firm investment.

ing, including the numerical challenges in solving them with Euler-equation-based methods (Krusell and Smith 2003, Maliar and Maliar 2005, 2016). As suggested by Maliar and Maliar (2016), we solve the model using the method of endogenous gridpoints (Carroll 2006). Time inconsistencies from hyperbolic discounting have been studied in the context of consumption-saving problems (e.g., Laibson 1997). Furthermore, the corporate finance literature has also suggested that myopic decision-making can lead to suboptimal equilibria (e.g., Stein 2003).

Further related is Aghion et al. (2010), which studies an investment model with two types of capital in the presence of credit constraints, but without considering managerial short-termism.

Our empirical results build on Edmans et al. (2017a,b) and Ladika and Sautner (2019) who show that managers with less equity-based compensation and hence stronger short-term incentives lower total investment. Relatedly, Asker et al. (2014) argue that private firms, whose management is presumably less prone to short-termism, have substantially higher capital expenditures and are more responsive to investment opportunities. We show that not only the level of investment but also the composition of investment across depreciation rates responds to short-term incentives.

The remainder of the paper is structured as follows. In Section 2, we present empirical evidence on the relation between managerial pay and investment. Sections 3 and 4 present our model and quantification. Section 5 concludes.

2 Empirical Evidence

In this section, we study the firm-level effects of short-termist managerial incentives. Our empirical analysis levers an accounting reform that provides a quasi-natural experiment that shifted managerial pay toward cash bonuses. We show that firms exposed to the reform (i) invested relatively more in investment projects with high depreciation rates and their weighted average depreciation rate increased, (ii) their self-reported discount rates increased, and (iii) their productivity decreased.

2.1 Accounting Reform

Since the composition of managerial pay across cash bonuses and equity-based compensation is endogenous, our main empirical analysis exploits an accounting reform, which is unrelated to economic fundamentals and incentive-contracting problems, and provides a shift of managerial pay toward cash bonuses. We study the effects of an unexpected and unprecedented reform of accounting practices for US firms caused by the revision of Financial Accounting Standard Board (FASB) Statement No. 123, or shortly FAS 123R.

In December 2004, the FASB revised the standards to account for transactions in which an entity exchanges its equity instruments for goods or services. The reform became effective for companies with their first full reporting period beginning after June 15, 2005. Before the reform, companies were allowed to expense equity-based compensation such as stock options or long-term incentive plans to employees at their intrinsic value.[6] This accounting standard allowed firms to provide equity-based compensation at very low accounting expenses. After FAS 123R, firms were obliged to expense equity-based compensation at fair value which effectively abolished the accounting advantage of option compensation.[7] The principal motivation behind the reform was to remove the accounting misrepresentation of the economic expenses for managerial pay. Other reasons for the revision were to simplify US Generally Accepted Accounting Principles (GAAP) and to make them more comparable with international accounting rules.

Firms that previously offered equity-based compensation substituted towards other forms of incentive compensation such as paying cash bonuses on profits. As profits are inherently more short-term than equity value, cash bonuses provide inherently more short-term incentives for managers. As part of the reform, the FASB additionally allowed firms to vest options prior to the original compliance date to accelerate the move towards fair-value accounting for equity compensation. This policy particularly incentivized the vesting of slightly in-the-money and out-of-money options, which further strengthened the short-termist shift of managerial incentives by the reform (see Ladika and Sautner 2019 and Edmans et al. 2017b).

We show that firms that offered equity-based compensation before the reform, subsequently substituted away from equity and equity-linked compensation, while not granting significantly more restricted stocks, and they reduced the duration of executive pay compared to other firms (see Section 2.4). Quantitatively, the duration of executive pay for managers of treated firms in our sample fell by around 2 months, compared to the pay duration of untreated firms (with a sample mean pay duration of about 1.5 years).

[6]The intrinsic value of an option is the difference between the firm's stock price on the date the equity option is granted and the strike price. Equity options with a strike price equal to the stock price have no intrinsic value and therefore generated zero accounting expenses under the old FAS 123 standard.

[7]Fair value means the option value of the upside potential in the stock price had to be accounted for.

2.2 Empirical Strategy and Data

Empirical Strategy: To identify the effect of managerial incentives on investment decisions, we compare the investment behavior of firms, that were most affected by the reform, to the investment behavior of less affected firms in the period around FAS 123R. We consider all firms whose CEOs had outstanding options in the pre-reform year 2004 as treated firms. These firms are directly affected by the reform because the costs of equity-linked compensation effectively increased for firms that compensated managers with options before FAS 123R while firms that did not choose to offer options before 2005 did not necessarily face any additional costs. In addition, firms that compensated managers with options before FAS 123R were allowed to let these options vest earlier, effectively reducing the duration of executive compensation while non-option-paying firms remained unaffected.

We estimate the following within-firm triple-differences specification, where the outcome $invest_{ict}$ denotes investments by firm i in investment category c at time t:

$$\begin{aligned} invest_{ict} =& \beta_1 \left(\text{FAS123}_t \times \text{Option}_{i,2004} \times \delta_c \right) + \beta_2 \left(\text{FAS123}_t \times \delta_c \right) \\ &+ \beta_3 \left(\text{Option}_{i,2004} \times \delta_c \right) + \lambda_{it} + \lambda_{c(i)} + \varepsilon_{ict}. \end{aligned} \tag{1}$$

We transform categroy-specific investment expenditures using the inverse hyperbolic sine function in our baseline estimations.[8] Investment categories differ in their depreciation rate δ_c. FAS123_t is a step dummy that equals one for years succeeding the reform (i.e., for $t > 2005$) and zero otherwise. $\text{Option}_{i,2004}$ is our firm-specific treatment indicator, which equals one for firms in which the CEO has outstanding (unexercised) equity options in 2004 and zero otherwise. The regression further contains firm-year fixed effects, λ_{it}, which absorb unobserved firm-year specific demand or supply factors that affect investment decisions. Hence, our identification is based on within-firm variation across investment categories for a given time period. Finally, $\lambda_{c(i)}$ contains either investment category (c) fixed effects, or category-firm (ci) fixed effects to control for differences in firms' production

[8] Formally, $invest_{ict} = \text{arsinh}\left(I_{ict}\right) = \ln\left(I_{ict} + \sqrt{I_{ict}^2 + 1}\right)$. This transformation has the advantage that we include zero investments in our estimations while we get $\text{arsinh}\left(I_{ict}\right) \to \ln 2 + \ln I_{ict}$ for large investment expenditures such that the interpretation is almost identical to a log regression. To address the concern in Mullahy and Norton (2022), we consider as alternatively outcomes investment rates (I/K) and $\log(I)$. Our results are robust to these alternative outcomes, see Section 2.4.

functions. In the latter case, λ_{ci} absorbs the regressor $(\text{Option}_{i,2004} \times \delta_c)$. The coefficient of interest is β_1, which captures the relative change of investment after FAS 123R in high-depreciation capital goods for firms with outstanding CEO equity options in 2004. If the reform induces exposed firms to adjust their investment composition towards short-term investment projects, β_1 is expected to be positive.

We further identify the effects of managerial incentives on firms' depreciation rates, discount rates and total factor productivities. In contrast to investment, for which we observe within-firm variation across investment categories, we observe these outcomes at the firm-year level. We therefore estimate the following difference-in-differences regressions:

$$y_{it} = \beta_1 \left(\text{FAS123}_t \times \text{Option}_{i,2004}\right) + \beta_2 \times \Delta_{it} + \lambda_i + \lambda_t + \varepsilon_{it}, \qquad (2)$$

where y_{it} is the firm-level outcome. Δ_{it} is a vector of controls which includes the level of capital stocks, firms' costs of capital and in some specifications a treatment-specific linear trend (t $\times$ $\text{Option}_{i,2004}$). The parameter of interest is again β_1. It captures the relative change of an outcome after the FAS 123R reform for firms with outstanding CEO equity options in 2004 relative to firms without outstanding CEO equity options.

Data: Our empirical analysis uses balance sheet data for listed US firms from Compustat and FactSet, as well as data on executive compensation from ExecuComp. We focus on a period around the 2005 accounting reform from 2000 to 2014. The data allow us to distinguish seven different investment categories, notably: land, buildings, machinery, transport equipment, R&D, computer equipment, and advertising. We obtain annual expenses on R&D and advertising from Compustat. Data on the remaining investment categories are obtained through Factset.[9] Our sample contains 725 firms.[10] Table 1 provides a summary of category-specific investment across firms and years.[11] On average, we observe the largest investments in machinery, R&D and advertising, whereas investments into land and IT are typically smaller.

Our subsequent empirical analysis examines an essential dimension in which the investment cat-

[9]We use a perpetual inventory method to transform stock variables into annual gross investment.

[10]We only keep firms in the sample that are classified as active in Compustat. We exclude firms that entered after 2004 and we exclude firms in the utilities, financial, and public sectors. For further details on the sample composition, see

Table 1: Selected Summary Statistics

Variable	Mean	Std. Dev.	p10	p25	p50	p75	p90	Obs
Firm-Investment Data								
Land	33.82	461.50	0.00	0.07	1.53	8.47	34.82	4,966
Buildings	100.97	404.21	0.90	3.34	13.45	52.49	193.62	7,335
Machines	438.52	2,046.36	6.02	20.56	75.32	272.57	909.52	7,300
Transport	141.79	590.74	0.06	0.37	2.35	21.49	260.14	938
Research	279.38	900.53	0.00	3.16	29.56	130.58	522.10	6,764
Computer	101.04	300.98	3.85	9.81	24.03	80.25	199.37	1,979
Advertising	240.92	607.38	1.34	6.21	38.07	164.46	619.67	4,625
Firm Data								
Depreciation Rate	15.35	10.01	7.04	10.42	12.69	18.09	25.44	10,532
Corporate Discount Rate	14.61	2.41	11.89	12.96	14.36	15.98	17.71	6,199
TFP	0.01	0.44	-0.41	-0.20	0.02	0.23	0.46	10,461
Compensation Data								
Option Dummy	0.797	0.402	0	1	1	1	1	725

Notes: The table presents summary statistics across firms and years from 2000 through 2014. Investment expenditures are denoted in millions of USD (deflated to year 2000 capital prices). Depreciation and discount rates are measured in %, TFP is denoted in logs. Option Dummy takes 1 if any unexercised options are outstanding, zero otherwise.

Table 2: Investment Categories and Depreciation Rates

Category	*Land*	*Buildings*	*Machines*	*Transport*	*R&D*	*Computer*	*Advertising*
Depreciation	0%	3%	12%	16%	20%	30%	60%

Notes: Estimates of depreciation rates are based on the survey of the literature in Garicano and Steinwender (2016).

egories differ, which is their depreciation rate. Table 2 presents estimates of investment category-specific depreciation rates based on the survey of the literature in Garicano and Steinwender (2016). We construct firm-year depreciation rates as averages of the category-specific depreciation rates weighted by the capital shares for a given firm-year observation. In addition, we use data on corporate discount rates from Gormsen and Huber (2022) based on firms' earnings calls. We further estimate firm-year revenue TFP as the residual when regressing log sales on log labor expenses and log capital costs, including a full set of 2-digit SIC industry fixed effects. Table 1 documents the distribution of depreciation rates, discount rates, and TFP across firms and years.

Finally, we use ExecuComp data to construct $\text{Option}_{i,2004}$, which equals one for firms in which the

Appendix A.1.

[11]Some categories of firm-level investment are frequently missing. Our empirical analysis considers all category-firm-year observations as long as we observe at least two investment categories per firm-year.

CEO has unexercised outstanding equity options in 2004 (before the reform) and zero otherwise. The last row of Table 1 summarizes the distribution of the dummy variable across firms. For 80% of firms, the CEO had outstanding equity options in 2004.

2.3 Main Results

Investment: Table 3 presents the main empirical result of this paper. It shows the estimated coefficients of equation (1) for different specifications of depreciation, fixed effects and sample periods. In parentheses, we show standard errors which are clustered at the firm-level following Abadie et al. (2023). The main coefficient of interest is β_1, which is associated with ($\text{FAS123}_t \times \text{Option}_{i,2004} \times \delta_c$). Across all specifications, the estimate of β_1 is positive and statistically significant at the 5% level or lower. Thus, we robustly find a relative increase of investment in high-depreciation capital goods after the accounting reform for firms with outstanding CEO equity options in 2004.

We next discuss the different specifications in Table 3. In the upper panel, we use the depreciation rates in Table 2 as measure of depreciation (Depr). In the lower panel, we use as measure of depreciation the ordinal rank of capital categories, ranging from 1 (for land) to 7 (for advertising). The ordinal rank addresses concerns associated with the specific estimates of depreciation rates in Table 2. Between columns (1) and (2), we replace the investment-category fixed effect with a category-firm fixed effect to account for idiosyncratic differences in production technologies across firms. The first two columns are based on a wide sample around the reform. While this helps to capture relative differences in investment that build up slowly, e.g., because of time-to-plan and time-to-build frictions, it increases the risk that our estimates capture later unrelated reforms and developments. We therefore repeat the analysis for a short sample around the reform in columns (3) and (4). Finally, we address the concern of potential pre-trends by controlling for the interaction between a linear time trend, the option dummy, and the depreciation measure in column (5). All specifications qualitatively reconfirm our finding. Quantitatively, the coefficient estimates imply that firms exposed to the reform shift about 5 to 10% more investment to a category with a 10 percentage point higher depreciation rate compared to non-exposed firms.

To estimate how the effects of the reform evolve over time, we regress investment expenditures on the interaction terms between year dummies, depreciation rates, and the treatment dummy. We

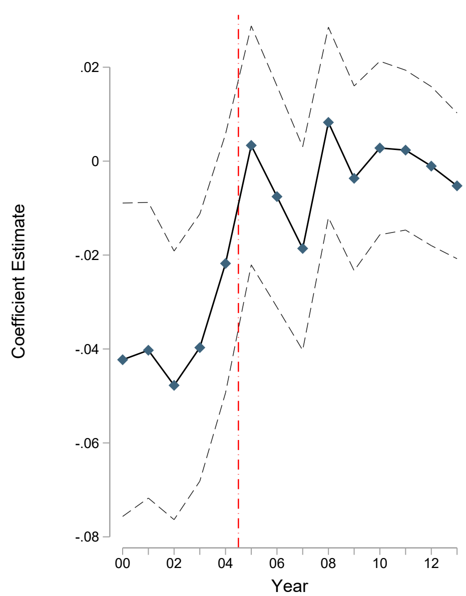
Table 3: Incentives and the Durability of Investments

	Investments				
	(1)	(2)	(3)	(4)	(5)
Measure of Depreciation:	*Depreciation Rate*				
FAS123 × Option × Depr	0.999	0.668	0.721	0.462	0.805
	(0.247)	(0.216)	(0.233)	(0.186)	(0.254)
FAS123 × Depr	-0.766	-0.344	-0.673	-0.421	-0.766
	(0.209)	(0.197)	(0.199)	(0.166)	(0.209)
Option × Depr	-0.303		-0.387		-54.03
	(0.344)		(0.355)		(39.71)
Measure of Depreciation:	*Ordinal Rank*				
FAS123 × Option × Depr	0.0920	0.0560	0.0693	0.0423	0.0625
	(0.0254)	(0.0208)	(0.0253)	(0.0197)	(0.0266)
FAS123 × Depr	-0.0571	-0.0130	-0.0620	-0.0360	-0.0570
	(0.0222)	(0.0189)	(0.0224)	(0.0176)	(0.0222)
Option × Depr	-0.0596		-0.0688		-8.214
	(0.0349)		(0.0346)		(4.172)
Category FE	×		×		×
Category-Firm FE		×		×	
Firm-Year FE	×	×	×	×	×
Time Trend					×
Observations	32,947	32,875	13,097	12,941	32,947
No. Firms	681	677	666	661	681
Sample Period	2000 - 2014	2000 - 2014	2002 - 2007	2002 - 2007	2000 - 2014

Notes: The Table reports various estimates of equation (1). *Option* is a dummy that indicates if any unexercised options are outstanding in 2004. *FAS123* takes value 0 for each year until 2005 and value 1 afterwards. *Depr* is the measure of depreciation, expressed in absolute depreciation rates in the upper panel and following an ordinal scale in the lower panel. Column 5 additionally includes a treatment-specific linear trend: Trend × Option × Depr. Standard errors (reported in parentheses) are clustered at the firm-level.

plot the estimates for each year in Figure 1. We find a persistent increase of relative investment in high-δ projects in the years following the reform. We can reject the null hypothesis that pre-FAS-123R coefficients equal their post-FAS-123R counterparts at the 1%-level. The 2004 point estimate, however, suggests that the investment composition has started shifting in 2004 already. There may be two underlying reasons. First, we assign firms to calendar years according to the fiscal year in Compustat (`fyear`). The fiscal year is the calendar year that includes the majority of days. For example, a firm closing its accounting year in May 2005 has a fiscal year equal 2004. Hence, investment in fiscal year 2004 may include investments after the reform was decided in December 2004. The second potential reason is that some firms may have anticipated the reform leading to an earlier response in the allocation of investment.[12]

Figure 1: Incentives and the Durability of Investments over Time



Notes: The Figure plots time-specific coefficients when category-specific investments are regressed on the interaction between an option dummy with year dummies and durability ranks. Category-firm and year fixed effects are included, standard errors are clustered at firm-level. Dashed lines illustrate 95% confidence intervals.

Depreciation rate: We next show that the depreciation rate of firms exposed to the reform increases relative to non-exposed firms. We use the firm-level difference-in-differences regression

[12] Figure A.3 in the Appendix highlights that there already was media coverage on the reform in U.S. business media in 2004.

in equation (2) with the firm-specific depreciation rates as the dependent variable, controlling for capital stocks and perceived costs of capital.[13] The upper panel of Table 4 shows our estimates. The depreciation rate increased for treated firms relative to untreated firms. Quantitatively, the depreciation rate increased by roughly 1 percentage point compared to the control group.

Corporate Discount Rates: Our empirical analysis builds on the hypothesis that the shift in managerial compensation away from equity-based compensation changes managers' incentives to focus more on short-term profits rather than long-term value. The evidence on investment and depreciation is consistent with this hypothesis. An alternative immediate test of the hypothesis is whether managers exposed to the reform use higher rates to discount future profits. We use recent data from Gormsen and Huber (2022), who measure the discount rate as the minimum required return on new investments announced in earning calls. The mid panel of Table 4 shows our estimates, controlling for the level of capital stocks (in logs) and the costs of capital. The reform had significant effects on the discount rates that managers use to evaluate investment opportunities. Compared to untreated firms, managers of treated firms discounted future cash flows by approximately 0.1-0.4 percentage points more.

Total Factor Productivity: We further estimate the impact of the reform on firm productivity. If the investment reallocation of the reform is such that capital becomes more misallocated across categories within firm, then we should expect firm-level TFP to fall. The bottom panel of Table 4 provides our estimates when the dependent variable is firm-level TFP. We find that treated firms experience a significant TFP reduction of approximately 5-9% relative to untreated firms, depending on the time sample considered. The evidence hence suggests that the reform raised within-firm capital misallocation.

2.4 Sensitivity Analysis

Ex-ante Differences: In Table A.2, we compare firms by treatment status. Treated firms are larger (in various metrics of firm size), invest relatively less in intangibles, have a lower share of liquid

[13] Perceived costs of capital are a firm's internal estimate of a weighted average of costs of debt and equity, obtained from Gormsen and Huber (2022).

Table 4: Incentives, Capital Stock Depreciation and Corporate Discount Rates

	(1)	(2)	(3)
	Weighted Average Depreciation Rate		
FAS123 × Option	1.383	0.931	1.196
	(0.529)	(0.537)	(0.619)
Observations	9,304	3,757	9,304
No. Firms	695	679	695
	Corporate Discount Rate		
FAS123 × Option	0.136	0.445	0.362
	(0.148)	(0.158)	(0.187)
Observations	5,972	2,321	5,972
No. Firms	546	478	546
	TFPR		
FAS123 × Option	-0.0911	-0.0554	-0.0937
	(0.0374)	(0.0303)	(0.0416)
Observations	9,243	3,701	9,243
No. Firms	652	648	652
Year FE	×	×	×
Firm FE	×	×	×
Trend			×
Sample Period	2000 - 2014	2002 - 2007	2000 - 2014

Notes: The Table reports various estimates of equation (2) with depreciation rates, discount rates and firm-level TFP as dependent variables. In the upper panel, we use the firms' average depreciation rates weighted by capital stocks in the individual categories as the dependent variable. In the mid panel, the outcome is the firms' self-reported corporate discount rates from Gormsen and Huber (2022). The bottom panel uses the firms' TFPR as the dependent variable. We compute TFPR as regression residuals from regressing log sales on log capital costs and the log of labor expenditures and 2-digit SIC industry fixed effects. *Option* is a dummy that indicates if any unexercised options are outstanding in 2004. *FAS123* takes 0 for each year until 2005, 1 afterwards. All columns in the upper two panels (weighted average depreciation rates and corporate discount rates) control for the level of capital stocks (in logs) and the costs of capital. Column 3 additionally includes *Trend* × *Option*. Standard errors (reported in parentheses) are clustered at the firm-level.

assets, have a lower equity volatility, and pay more to their CEOs in terms of current compensation. To address the concern that these (ex-ante) differences may drive our main result, we repeat the analysis controlling for these ex-ante differences (adding further triple interaction terms in equation 1). We find that neither controlling for size differences (Table A.3) nor controlling for the other ex-ante differences listed above (Table A.4) dramatically change our finding in Table 3. It appears unlikely that our main finding is driven by ex-ante differences of treated and untreated firms.

CEO Turnover: A possible concern is that the compensation scheme may differ for CEOs that are newly appointed or close to loosing their job, which may also affect the CEOs' investment incentives. To address this concern we focus on the subsample of firms without CEO turnover during the sample period. Compared to Table 3, the estimates for the subsample in Table A.5 are larger and more significant. The estimated effects of the reform are more pronounced and more precisely estimated when excluding firms with CEO turnover.

Alternative Measurement of Investments: In Table A.6, we consider alternative outcomes to the inverse hyperbolic sine transformation of the investment variable $invest_{ict}$: investment shares, log(investment), or log(1+investment). Compared to Table 3, we find that our results are robust to these alternative transformations.

Short-term Incentives: A potential concern is that the reform did not change manager compensation in a way that provides more short-term incentives. If the accounting reform caused firms to substitute towards restricted stock and previous options had short vesting dates, incentives would become more long-term. We can reject this hypothesis: Managers in treated firms experienced a significant reduction in non-current compensation compared to managers of untreated firms around the reform, see Table A.1. In addition, there was no significant increase in grants of restricted stock to executives in treated compared to untreated firms.[14] Additionally, we study how managers' pay duration changed around the reform. Gopalan et al. (2014) measure the duration of executive pay as a weighted average vesting period of different pay components, thereby quantifying the extent to which compensation is short-term and document an average duration around 1.5 years. Managers

[14] The overall level of restricted stock grants increased after FAS 123R (see Hayes et al. 2012), but this increase does not significantly differ between treated and untreated firms.

of treated firms in our sample experience a reduction of around 2 months pay duration, compared to those of untreated firms. We have further shown that firms exposed to the reform increased the discount rates used to evaluate investment opportunities (see Table 4), additionally confirming a switch toward short-term incentives.

Intangibles: Our results might be driven by intangibles, which can be directly expensed under US GAAP rules. To address whether intangibles drive our results, we repeat our analysis separately for tangibles and intangibles and when excluding R&D expenditures. Our results are broadly similar to the baseline suggesting that the alternative explanation is not a key factor (see Table A.7).

Capital Stocks: The shift toward investment in high-depreciation capital goods should imply a shift in the composition of the capital stock toward high-depreciation capital goods. However, this shift is partly dampened by the higher deprecation rate itself. To test the effects of the reform on capital reallocation, we construct category-specific capital stocks (in logs) and include them as an alternative dependent variable in our baseline regressions. The results from Table A.10 demonstrate that the introduction of FAS 123R led to substantial reallocation of capital within firms. On average, treated firms increased the stock of a capital category with a 10 percentage point higher depreciation rate by about 2 to 12% compared to untreated firms (based on the upper panel).

2.5 Evidence Beyond the Accounting Reform

The final part of our empirical analysis estimates the association between investment and managerial equity ownership. At the expense of weaker identification, we go beyond the variation induced by the accounting reform and show that managers with more short-term incentives tend to allocate relatively more investment toward high-deprecation capital goods.

To measure the short-term incentives of managers, we construct the share of firm equity owned by the manager, shortly: the managerial ownership share. The idea here is that managers with a larger ownership share have incentives that are more closely aligned with long-term equity value maximization. The managerial ownership share is further central in the theory we develop in Section 3. We define the managerial ownership share for firm i and year t as the ratio of the CEO's firm-related wealth over the market capitalization of the firm:

$$\eta^e_{it} = \frac{\text{Firm-related Wealth}_{it}}{\text{Market Capitalization}_{it}}.$$

We obtain data on CEOs' firm-related wealth from Coles et al. (2006) who use Compustat Execucomp data to construct a measure of managers' equity ownership.[15] We estimate the following empirical specification based on our firm-investment panel from 2000 to 2014:

$$invest_{ict} = \beta_1 \left(\eta^e_{it} \times \delta_c\right) + \beta_2 \, \eta^e_{it} + \lambda_{ci} + \lambda_{t(i)} + \varepsilon_{ict}. \tag{3}$$

Our parameter of interest is β_1, which captures the relative change of investment in high-depreciation capital goods for firms with higher managerial ownership. Table 5 presents our findings. The estimates of β_1 are negative in all specifications, which suggests that reductions in managerial ownership are associated with relatively more investment in short-term asset categories. Alternatively, we interact our measure of managerial ownership with dummies for each investment category. Consistent with Table 5, we find that investments in more durable projects, such as land or buildings, depend more strongly on managerial equity ownership compared to investments in less durable projects, such as computer equipment or advertising, see Figure A.2.

3 Model

The previous section established empirically that a shift toward short-term managerial compensation leads to relatively more investments in projects with high depreciation rates, higher weighted average depreciation rates, higher discount rates, and lower productivity. In this section, we develop a model to rationalize the empirical evidence and to understand its implications for firms and the economy. In the model, firms produce using two types of capital goods that differ in their depreciation rate. Investment decisions are made by a risk-neutral manager who maximizes the present value of her compensation package, which includes a cash bonus based on current profits and equity compensation.

[15] Core and Guay (2002) use the same methodology to construct managerial equity wealth based on Execucomp.

Table 5: Equity Ownership and the Durability of Investments

	Investments			
	(1)	(2)	(3)	(4)
Measure of Depreciation:	*Dep. Rate*		*Ordinal Rank*	
Equity Share × Depr	-0.355	-0.254	-2.500	-1.461
	(0.123)	(0.132)	(1.280)	(1.318)
Equity Share	0.635		-0.200	
	(0.614)		(0.428)	
Category-Firm FE	×	×	×	×
Year FE	×		×	
Firm-Year FE		×		×
Observations	29,330	28,611	29,330	28,611
No. Firms	672	649	672	649
Sample Period	2000 - 2014	2000 - 2014	2000 - 2014	2000 - 2014

Notes: The Table reports the results on the relationship between managerial equity ownership and investment decisions. *Equity Ownership* is the CEO's ownership share. *Depr* is the measure of depreciation, expressed in absolute depreciation rates in columns 2 and 3 and following an ordinal scale in columns 4 and 5. Standard errors (reported in parentheses) are clustered at the firm-level.

Production and Profits: Consider a firm that uses labor N_t and a set of two capital inputs $\mathbf{K}_t = [K_{lt}, K_{st}]$, a short-lived and a long-lived capital good with the associated depreciation rates given by $0 < \delta_l < \delta_s < 1$. The firm produces output Q_t according to the Cobb-Douglas production function

$$Q_t = ZF(\mathbf{K}_t, N_t) = Z\left(K_{lt}^{\nu} K_{st}^{1-\nu}\right)^{\alpha} N_t^{1-\alpha}, \tag{4}$$

where Z denotes firm productivity. The firm faces isoelastic demand, $Q_t = BP_t^{-\varepsilon}$, where B is a demand shifter and ε a demand elasticity. In combination with (4) this yields revenues

$$R_t = P_t Q_t = X^{1-a-b}\left(K_{lt}^{\nu} K_{st}^{1-\nu}\right)^{a} N_t^{b}, \tag{5}$$

where $X^{1-a-b} \equiv B^{1/\varepsilon} Z^{1-1/\varepsilon}$ captures the firm's overall business conditions, and $a \equiv \alpha(1-1/\varepsilon)$, $b \equiv (1-\alpha)(1-1/\varepsilon)$. Capital is subject to time to build and follows the law of motion

$$K_{jt+1} = (1-\delta_j)K_{jt} + I_{jt}, \quad j \in \{l, h\}, \tag{6}$$

where I_{jt} denotes gross investment for capital type j. Investment is subject to quadratic adjustment costs.[16] Total capital expenses, including direct investment costs and adjustment costs, are given by

$$C_t^K = \sum_{j \in \{l,s\}} \left[(K_{jt+1} - (1-\delta_j)K_{jt}) + \gamma \left(\frac{K_{jt+1}}{K_{jt}} - 1 \right)^2 K_{jt} \right]. \tag{7}$$

Labor adjustment is frictionless and we denote the wage rate by w. Hence, period t profits are

$$\Pi_t = R_t - wN_t - C_t^K. \tag{8}$$

Manager Compensation: The decision-maker in the firm is a manager. The manager's compensation consists of a fixed salary w_t^f that is independent of firm performance, a cash bonus that is a share of current profits $\eta^b \Pi_t$ with $\eta^b \in [0,1)$, and equity compensation that is proportional to total equity $\eta^e E_t$ with $\eta^e \in (0,1)$.[17] Hence, total manager compensation is given by:

$$\Gamma_t = w_t^f + \eta^b \Pi_t + \eta^e E_t. \tag{9}$$

The important feature of manager compensation is that it partly depends on current (short-term) profits, and partly on long-term firm value. As in Nikolov and Whited (2014), we do not derive the optimal compensation contract but instead model the compensation contracts that we observe in the data. This approach allows us to identify the effects of changing contractual features on firms' investment policies, the allocation of capital and economic activity. To keep the model tractable, we follow Glover and Levine (2015) in assuming that contracts last for one period and that the manager does not hold shares in the firm at the beginning of the period.[18]

The market value of equity E_t depends on the discounted stream of expected dividends. After taking into account salaries and bonuses for management, the total amount available for dividend

[16]We have examined versions of the model with partially irreversible investment and adjustment cost parameters γ differing across capital goods. These model variations did not affect our results in a qualitatively meaningful way.

[17]We abstract from three peculiar cases: $\eta^b = 1$, $\eta^e = 0$, or $\eta^e = 1$. In all three cases, either $\beta = 0$ or $\theta = 0$ meaning the manager's compensation does not depend on future profits. Given one-period time to build, the firm's capital stock will then converge toward zero, because each successive manager will not find it optimal to buy capital.

[18]Considering multi-period contracts between managers and owners complicates the model solution and may require further structural assumptions. These include *i*) managers' preferences regarding payoffs at different points in time, *ii*) managers' ex-ante exposure to the firm's performance via pre-existing holdings of equity, *iii*) a process linking managers' probability of staying with the firm to firm performance and *iv*) uncertainty about future remuneration packages.

payments in each period t is given by $(1-\eta^b)\Pi_t - w_t^f$. In addition, in each period t the manager in charge receives a share η^e of equity, leading to share dilution.[19] With complete financial markets and rational expectations, the value of firm equity is recursively defined by

$$E_t = (1-\eta^b)\Pi_t - w_t^f + \frac{1}{1+r}\mathbb{E}_t\Big\{(1-\eta^e)E_{t+1}\Big\}, \tag{10}$$

where r is the risk-free market interest rate. After recursive substitution of (10), we can rewrite the value of the manager's compensation package in (9) as

$$\Gamma_t = w_t^f - \eta^e \sum_{\tau=0}^{\infty} \theta^\tau \mathbb{E}_t\Big\{w_{t+\tau}^f\Big\} + \varphi\left[\Pi_t + \beta\sum_{\tau=1}^{\infty}\theta^\tau\mathbb{E}_t\Big\{\Pi_{t+\tau}\Big\}\right], \tag{11}$$

where

$$\varphi \equiv \eta^b + \eta^e(1-\eta^b), \quad \beta \equiv \frac{\eta^e(1-\eta^b)}{\eta^b+\eta^e(1-\eta^b)}, \quad \theta \equiv \frac{1-\eta^e}{1+r}. \tag{12}$$

Because the term $w_t^f - \eta^e \sum_{\tau=0}^{\infty}\theta^\tau\mathbb{E}_t\{w_{t+\tau}^f\}$ is exogenous to the manager's decision problem we will ignore it in the following and focus on the last term in (11).

The payout profile in (11) is akin to the preferences of a risk-neutral agent with quasi-hyperbolic discounting preferences over the stream of profits Π_t (see Laibson 1997). These preferences feature present bias when $\beta < 1$, which captures how strongly managers discount future profits relative to current profits. Present bias arises when the cash bonus share of current profits is strictly positive, $\eta^b > 0$. Increasing the bonus share η^b, or lowering the equity share η^e when $\eta^b > 0$, reduces β and thus increases the present bias towards current profits. Furthermore, $\theta < \frac{1}{1+r}$ incorporates the equity dilution factor $(1-\eta^e)$, which results in stronger discounting of future profits. Stronger discounting arises because the present manager's equity compensation is diluted by future managers also receiving equity compensation.

Investment Problem: In every period t, the current manager decides how much to invest in each type of capital and how much labor to hire. Formally, the manager chooses an action $a_t = (\mathbf{K}_{t+1}, N_t)$ depending on the history of previous managers' decisions $\mathcal{H}_t = (a_s | s < t)$. Denote by s_τ a strategy

[19] Shareholders in period t anticipate that the share of future total market capitalization they hold shrinks by a factor of $1-\eta^e$. The effect of equity-based compensation on share dilution is a well-known fact in finance (see, e.g., Asquith and Mullins 1986, Huson et al. 2001, Core et al. 2002).

of manager τ. The decision problem of the manager in t is

$$\max_{a_t} \Gamma_t \quad \text{s.t.} \quad (8), \tag{13}$$
$$\text{given } \mathcal{H}_t, \text{ and beliefs regarding } s_\tau, \tau > t.$$

Generally, this type of problem has an extremely large strategy space and a multitude of equilibria can occur. Although a thorough examination of the strategy space of such a game may seem interesting, we focus on symmetric, smooth Markov-perfect equilibria, where the state of the game is entirely described by a_{t-1}, in line with most macroeconomic models.

While static labor demand has a well-known analytical solution,[20] it is not possible to analytically solve for the policy functions regarding the two capital goods in the presence of capital adjustment costs. Instead, we implicitly characterize a time-invariant policy function, assuming that the policy functions of all managers only depend on the current capital goods and that future managers will behave in the same way. We denote this function as $\mathcal{K}(\mathbf{K}) = (\mathcal{K}_l(\mathbf{K}), \mathcal{K}_s(\mathbf{K}))$, where $\mathcal{K}_j(\mathbf{K})$ is the policy function for capital good $j \in \{l, s\}$. That is, in period t a manager whose firm starts with capital stocks $\mathbf{K}_t = (K_{lt}, K_{st})$ chooses $K_{j,t+1} = \mathcal{K}_j(\mathbf{K}_t)$. The function $\mathcal{K}(\cdot)$ is the solution to the manager's first-order conditions associated with (8). With a slight abuse of notation, the policy function will be the solution $\mathbf{K}_{t+1}$ of the following self-referencing characterization for j:[21]

$$0 = \frac{\partial \Pi_t}{\partial K_{j,t+1}} + \beta\theta \frac{\partial \Pi_{t+1}}{\partial K_{j,t+1}} + \beta\theta \sum_{k=\{l,s\}} \frac{\partial \mathcal{K}_k(\mathbf{K}_{t+1})}{\partial K_{j,t+1}} \left[\frac{\partial \Pi_{t+1}}{\partial K_{k,t+2}} + \frac{\partial V(\mathcal{K}(\mathbf{K}_{t+1}))}{\partial K_{k,t+2}} \right]$$

$$0 = \frac{\partial \Pi_t}{\partial K_{j,t+1}} + \beta\theta \frac{\partial \Pi_{t+1}}{\partial K_{j,t+1}} + \theta(1-\beta) \sum_{k=l,s} \frac{\partial \mathcal{K}_k(\mathbf{K}_{t+1})}{\partial K_j} \frac{\partial V(\mathcal{K}(\mathbf{K}_{t+1}))}{\partial K_k}. \tag{14}$$

Here, the term $V(\cdot) := [\Pi_t + \theta V(\mathcal{K}(\mathbf{K}_t))]|_{\mathbf{K}_t}$ represents a recursive continuation value, conditional on the current choice of capital inputs. This capital-specific Euler equation (14) takes into account the strategic dependence of future behavior on current decisions. The first two elements are fairly standard: the first element incorporates the current costs of investment (including the unit prices of

[20] Profit-maximizing labor demand satisfies $N_t = \left(bX^{1-a-b}\left(K_{lt}^{\nu} K_{st}^{1-\nu}\right)^a w^{-1}\right)^{\frac{1}{1-b}}$.

[21] The derivation of the optimality condition (14) is relegated to Appendix B.1.

capital goods and the marginal adjustment costs), the second term represents the marginal returns in the next period, discounted by $\beta\theta$, adjusted for depreciation. The final term is a peculiarity of our model and other models with quasi-hyperbolic discounting. This term captures the marginal effect on equity via changes in future investment behavior. Both, the unknown gradients of the capital policy functions $\frac{\partial \mathcal{K}_k(\mathbf{K}_{t+1})}{\partial K_j}$ for $j, k \in \{l, s\}$ as well as the unknown gradient of the continuation-value function $V(\cdot)$ are relevant to evaluate the effects of future investment on equity value. Whenever managers are compensated with a combination of bonuses and equity (which implies that $\beta \neq 1$), this last term does not cancel out such that this cannot be solved analytically and requires to be approximated numerically within the calibration exercise.

Discussion: While our model allows for fairly rich dynamics of investment, it abstracts from other factors that affect investment. One of these factors is managerial risk-aversion. While difficult to measure, a manager with high risk aversion may have an even stronger preference to tilt the within-firm capital allocation further towards short-term assets as these assets expose the decision-maker to less uncertainty in the future. We also neglect the role of convexity in compensation schemes. In our defense, Hayes et al. (2012) provide empirical evidence that the change in convexity induced by FAS 123R had little impact on CEOs' risk-taking behavior. In the baseline quantitative analysis, we further abstract from general equilibrium effects. GE price responses imply that the accounting reform also affects those managers whose compensation structure is not affected by the reform. At the end of this section, we study a general equilibrium extension of the model that takes these price effects into account.

4 Quantitative Analysis

We use our model to quantify the effects of a shift in managerial incentives on the capital allocation of firms and associated economic outcomes. The calibrated model rationalizes the empirical evidence on the accounting reform and predicts a sizeable output drop partly due to increased within-firm capital misallocation.

4.1 Calibration and Solution

A period in the model is a year. We calibrate the model to match the change in managerial compensation in the years around the accounting reform FAS 123R for a simulated sample of 1,000 firms. Model parameters not directly related to managerial compensation are calibrated to match salient features of the data before FAS 123R.

Calibrating Incentive Contracts: Table 6 summarizes equity and bonus shares (η^e and η^b) and the present bias β before and after the reform. We construct η^b as the ratio of the sum of bonuses and non-equity incentive compensation over firm sales. The equity share η^e is constructed dividing the managers' equity-linked firm wealth by their employing firms' market capitalization.[22] We compute β following equation (12). The sample mean of β falls by 3 percentage points from 0.918 to 0.890. This decrease of β is driven by both, reductions in the equity share η^e and increases in bonus shares η^b. For each simulated firm, we draw a pre- and a post-FAS-123R value of β that match the observed distributions of β in the data for the years 2005 and 2007. In particular, we discretize the distribution of β into 10 equally-sized bins ranging from 0.75 to 1.0 and compute the observed transition probabilities across bins for the pre-FAS-123R period 2005 to the post-FAS-123R period 2007.[23] About 70% of the firms remain in the same bin for β, while about 19% move to a bin with a higher value for β and only 11% enter a lower β-bin. Thus, the incentive structure of managers has shifted towards stronger present bias in the period around the reform. In addition, firms draw a value of η_e from a beta distribution that we fit to the distribution of observed η_e in the data.

Other Parameters: In order to capture heterogeneity in production functions and depreciation rates across sectors, we assign each firm to a specific sector. The allocation of firms to sectors is a random draw, where we use as probability weights the number of firms per sector in the US. We consider 13 sectors listed in Table 7. We calibrate the following parameters to match sector-specific moments: δ_l, δ_s, ν, α, w, ε, B. We calibrate the depreciation rates to sector-specific weighted

[22] Details on the computation can be found in Appendix C.1.

[23] Table A.11 in the Appendix provides the observed transition probabilities across bins. The shift in the distribution of β is plotted in Figure A.4.

Table 6: Summary Statistics on Incentive Contracts

Variable	Mean	Std. Dev.	p25	p50	p75	Obs
Bonus Share η_b						
2005	0.00034	0.00060	0.00004	0.00014	0.00036	7,786
2007	0.00046	0.00200	0.00005	0.00015	0.00041	8,534
Equity Share η_e						
2005	0.0097	0.0254	0.0009	0.0024	0.0067	7,786
2007	0.0063	0.0168	0.0006	0.0016	0.0045	8,534
Present Bias β						
2005	0.918	0.078	0.874	0.943	0.982	7,786
2007	0.890	0.087	0.803	0.910	0.968	8,534

Notes: The table reports summary statistics on the bonus shares η_b, the equity shares η_e and the associated values of β before and after the FAS 123R reform (2005 and 2007) constructed based on Execucomp, Compustat, Coles et al. (2006), Core and Guay (2002), and equation (12), see Appendix C.1 for details.

average depreciation rates when grouping capital goods into the long-lived category (buildings and structures) and the short-lived category (various types of equipment). We target the remaining parameters to match the sector-specific revenues R, the share of long-lived capital $\frac{K_l}{K_l+K_s}$, the ratio of long-lived capital over revenues $\frac{K_l}{R}$, the ratio of labor costs over revenues $\frac{wN}{R}$, and the wage rate w. We abstract from incentive distortions when calibrating these industry-specific production and demand parameters using the steady-state conditions of the model, see Appendix C.2 for details. Table 7 shows the calibrated industry-level model parameters.

The idiosyncratic firm productivity Z is drawn from a random log-normal distribution, where we assume that the logarithm of Z is distributed around a zero mean with a standard deviation of 0.52, which is what İmrohoroğlu and Şelale Tüzel (2014) find for the productivity dispersion in Compustat data. Each firm's overall business condition X is then the composite of an industry-wide demand condition B and the firm-specific TFP component Z, according to $X = B^{\frac{1}{\varepsilon}} Z^{\frac{\varepsilon-1}{\varepsilon}}$. For the quadratic adjustment-cost parameter γ, we follow Bloom (2009) and choose 4.844.[24] The interest rate r is set to 2.98%.

Solution Method: Since the incentive structure in the model features a present bias ($\beta < 1$), our model resembles a quasi-hyperbolic discounting problem. Hence, solving our model involves sim-

[24]We discuss the sensitivity of our results regarding γ in Appendix C.3.

Table 7: Industry-Level Parameters

Code	Industry Name	Industry Weight (in %)	Depreciation Rates		Production Function Parameters		Wage Rate (in Thd. USD, 2010 prices)	Demand Elasticity	Demand Shifter (in Thd. USD, 2010 prices)
			δ_l	δ_s	ν	α	w	ε	B
A	Agriculture, forestry and fishing	2.0	0.02	0.13	0.30	0.55	28.4	2.4	17,426
B	Mining and quarrying	0.3	0.02	0.14	0.79	0.58	113.5	2.3	184,719
C	Total manufacturing	7.9	0.03	0.11	0.27	0.24	57.4	3.4	22,978,000
D, E	Electricity, gas and water supply	0.5	0.02	0.10	0.59	0.55	58.1	3.3	628,381
F	Construction	12.6	0.03	0.16	0.13	0.07	51.5	2.9	3,633,884
G	Wholesale and retail trade	22.3	0.03	0.15	0.45	0.12	48.6	2.6	976,920
H	Transportation and storage	3.1	0.03	0.14	0.35	0.25	57.5	10.1	34,204 $\times 10^{12}$
I	Accommodation and food service activities	7.9	0.03	0.14	0.56	0.13	28.9	3.5	5,043,535
J	Information and communication	0.4	0.04	0.13	0.52	0.29	66.9	2.9	27,135,000
K	Financial and insurance activities	5.0	0.04	0.18	0.35	0.18	76.2	3.0	13,328,000
M, N	Other business services	17.8	0.04	0.15	0.28	0.13	81.3	4.0	563,140,000
Q	Healthcare	9.0	0.03	0.15	0.51	0.10	48.7	11.8	792,530 $\times 10^{15}$
R, S	Arts, entertainment and recreation	11.2	0.05	0.15	0.71	0.17	40.8	4.7	350,250,000

Notes: Industry weights are based on the number of enterprises across sectors from the OECD Structural Statistics of Industry and Services database for the year 2005. Other industry-level information is based on US 2003–2005 files from EU KLEMS data. Depr rate s displays the depreciation rate of the short-term capital stock, which is given by the capital stock-weighted depreciation rates of telecommunication equipment (N11322G), computer hardware (N11321G), transport (N1131G) and other machinery equipment and weapons (N11OG). Accordingly, depr rate l is the industry-specific long-term depreciation rate, that is directly provided by EU KLEMS (depreciation rate for other buildings and structures, N11OG). The last column displays the share of long-term capital in total capital.

ilar challenges as those documented in previous neoclassical growth models with quasi-geometric discounting (e.g. Krusell and Smith 2003, Maliar and Maliar 2016).[25] In particular, as the generalized Euler equation for capital does not have a specific closed-form solution, we resort to numerical methods. Since Euler-equation methods are likely to fail (cf. Maliar and Maliar 2016), we use a version of the endogenous gridpoint method first introduced by Carroll (2006). This method works similar to backward induction: for a fixed number of possible future stocks of both types of capital, one solves the managers' optimality conditions for current stocks. This procedure essentially constructs inverted policy functions from which we can back out the dynamics for each firm.

4.2 Results

We next show and discuss our quantitative findings. We first use our simulated sample of firms to estimate the investment response to the reform and compare them to the empirical estimates. Second, we study the dynamics of investment and output. Third, we discuss the implications for within-firm misallocation and productivity. Finally, we study the effects of the reform in general equilibrium.

Empirical Regressions on Simulated Data: A key test for our calibrated model is whether it can replicate the (non-targeted) empirical evidence in Section 2. We therefore run the regression in equation (1) on our simulated sample of firms. In contrast to the empirical sample, the simulated data only contain two types of capital. We define as treatment a dummy variable indicating whether the firm experienced a reduction in β. Table 8 reports our estimates. The estimates coincide in sign and are even fairly close in magnitudes compared to their empirical counterparts in Table 3. For example, when considering a 6-year sample and including fixed effects for investment categories and firm-year cells in column (3), we estimate an investment response of 0.714 for our simulated

[25]In the case without adjustment costs ($\gamma = 0$), a simple equilibrium is straightforward: since managers' utility is modelled as linear and markets are complete, the choice of $\mathbf{K}_t$ by manager $t-1$ only acts as a level shift to current profits. Hence, manager t's marginal calculations are separate from the current state of the capital stock. As such, the manager could simply choose an arbitrary value of $\mathbf{K}_{t+1}$ irrespective of $\mathbf{K}_t$. If all managers follow such a strategy, the gradients of the policy function are zero everywhere. In anticipation of this, future behavior cancels out of the model equations and the optimality conditions (14) for each capital good $j \in \{l, s\}$ simplifies to

$$1 = \beta\theta \left[\frac{\partial R(K_{lt}, K_{st}, N_t,)}{\partial K_{jt}} + (1 - \delta_j) \right].$$

data compared to 0.721 based on the analogous specification in real data. Across specifications, the estimates are not all as close to their empirical counterparts. Overall, however, the magnitudes are fairly similar.

In Table A.9 of the Appendix, we link the constructed structural parameter β back to our reduced-form estimates. There, we estimate that reductions in β are indeed associated with a shift of investments towards more short-lived capital goods. Moreover, we use $\text{FAS123}_t \times \text{Option}_{i,2004}$ as an instrument for β to confirm that the reform-induced shift in incentives caused a more short-term investment behavior.

Table 8: Simulated Firms - Regression Results

	Investments				
	(1)	(2)	(3)	(4)	(5)
Measure of Depreciation:	*Depreciation Rate*				
FAS123 × β Reduced × Depr	0.367	1.371	0.714	1.395	0.604
	(0.139)	(0.0797)	(0.116)	(0.0853)	(0.153)
FAS123 × Depr	0.902	-0.102	0.583	-0.0974	0.902
	(0.110)	(0.0121)	(0.0752)	(0.0115)	(0.110)
β Reduced × Depr	1.781		1.799		1.876
	(0.565)		(0.567)		(0.567)
Category FE	×		×		×
Category-Firm FE		×		×	
Firm-Year FE	×	×	×	×	×
Trend					×
Observations	30,000	30,000	12,000	12,000	30,000
No. Firms	1,000	1,000	1,000	1,000	1,000
Years around reform	15	15	6	6	15

Notes: This Table reports the results on the relationship between managerial incentives and investment decisions based on the panel of simulated firms. β *Reduced* is defined as dummy variable which indicates if a firm experiences an actual reduction in its firm-specific β. *FAS123* is a dummy variable indicating the post-shock period. Empirical specifications in columns 1 to 5 resemble those in Table 3. The treatment-specific linear trend in column 5 is Trend × β *Reduced* × Depr. Standard errors (reported in parentheses) are clustered at the firm-level.

Investment and Output: We next analyze the dynamic responses of investment, capital, and output to the shift in managerial incentives. For each firm, we compute the percentage change of several outcomes in the years around the reform relative to the pre-reform steady-state level. Figure 2 shows the average % change across firms (solid lines) as well as 95% confidence intervals across firms (dashed lines). Panel (a) shows the response of the total investment rate, defined as investment per capital stock. Firms respond to the increased present bias by cutting their investment. The immediate average reduction in the investment ratio is 1.1%.[26] The investment drop is more pronounced for long-term capital goods than for short-term capital goods. While the investment ratio for short-term capital initially falls by 0.5% on average, the initial drop in the investment ratio for long-term capital is 2.6%. This asymmetric response in investments is consistent with our empirical findings in Table 3. Consistent with lower investment rates, we observe a fall in the firms' capital stock, as shown in panel (c). Finally, panel (d) plots the response of output to the simulated reform. In the long-run, output falls by 0.5% on average.[27] We consider this a sizeable reduction in output, given that the cause is an accounting reform, which at first glance may pass as innocuous for the economy. Our findings highlight the importance of managerial incentives for real economic outcomes.

Since the capital composition shifts towards short-term capital goods, average depreciation rates of capital stocks increase, consistent with our empirical evidence. As a consequence, larger investment ratios are required in the new steady state.

Capital Misallocation and Productivity: In the model, misallocation within firms arises from the failure of managers to fully internalize the advantages of long-lived capital goods. This causes an imbalance in capital allocation with an excessive emphasis on short-term capital within the firm. Notably, static measures of TFP are uninformative in depicting this type of capital misallocation as these measures do not account for differences in costs of capital between capital goods.[28]

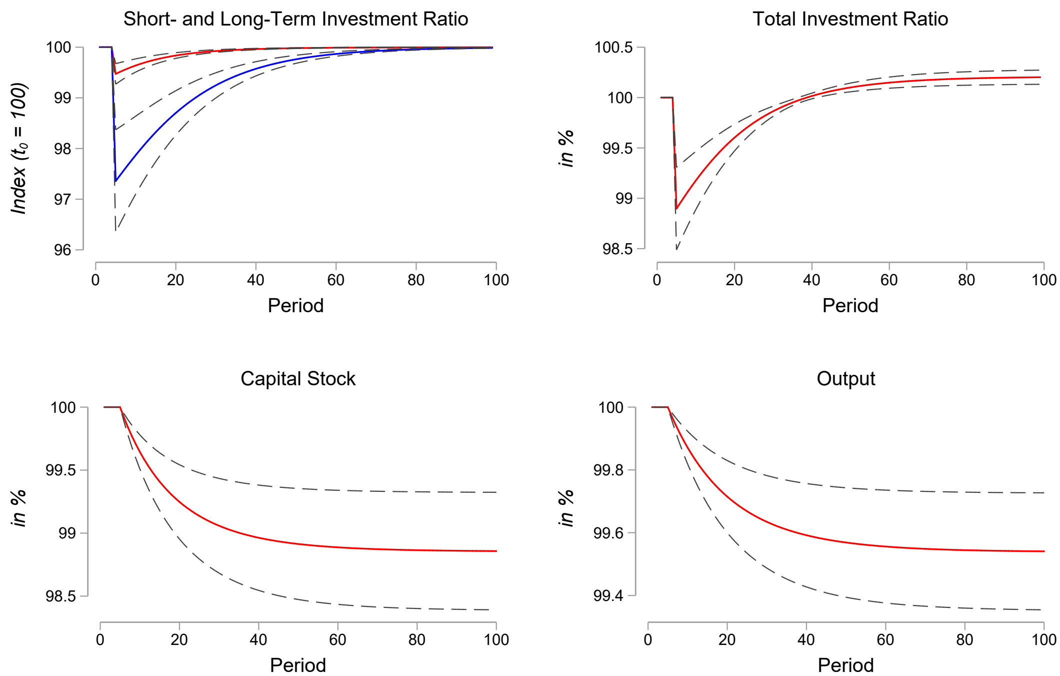
To map the distortive effects of capital misallocation within firms to long-run declines in productivity, we consider a measure of productivity that relates revenues to a weighted bundle of input

[26]The drop in investment is qualitatively consistent with empirical findings by Ladika and Sautner (2019), who report a reform-induced investment cut in the years directly after the introduction of FAS 123R.

[27]Due to the homogeneity of the production function and labor being a freely adjustable production factor, the observed relative decline in output is similar to the employment change.

[28]Independently of present bias, managers opt for long-term capital shares that exceed the output-maximizing shares ν. This inclination towards higher long-term capital shares is caused by profit-maximization, as long-term capital depreciates more slowly. When a negative shock to β exacerbates the present bias among managers and the long-term capital share decrease, thereby moving closer to the output-maximizing shares ν, a static measure of TFP increases, even though output and profits fall.

Figure 2: Investment and Output Adjustments within Firms



Notes: The Figure depicts the dynamic adjustments for investments and production output as averages across firms over time. All variable means are indexed to pre-shock values. The top-left graph depicts short-term investment in red and long-term investment in blue, both normalized by their respective capital stocks: I_{st}/K_{st} and I_{lt}/K_{lt}. The top-right graph depicts total investments normalized by the capital stock: $(I_{st} + I_{lt})/(K_{st} + K_{lt})$. The bottom-left graph depicts the level of the total capital stock: $K_{st} + K_{lt}$. The bottom-right graph depicts production output: Q_t. The dashed lines depict 95% confidence intervals.

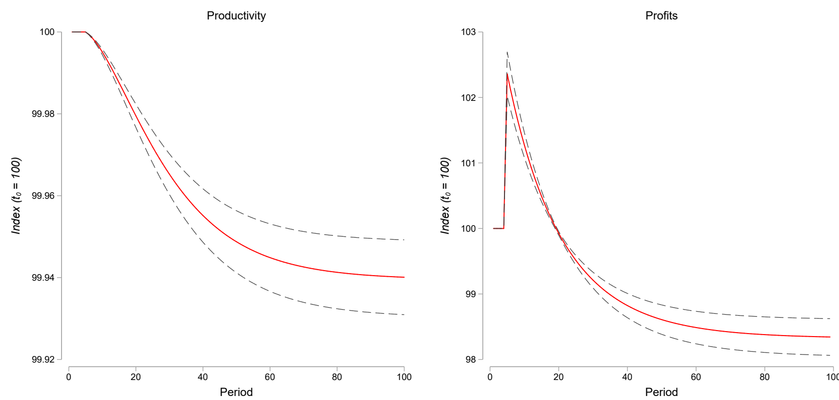
costs (analogously to the empirical analysis):

$$Productivity_t \equiv \frac{R_t}{(\delta_l K_{lt} + \delta_s K_{st})^a (wN_t)^{1-a}}. \tag{15}$$

In order to focus on the part of productivity loss that stems from misallocation of capital (ignoring the decline in overall firm scale), we hold the aggregate capital stock of each firm fixed and calculate counterfactual revenues and employment while keeping the composition of capital stocks variable, using the calibrated composition as outcomes. The left graph in Figure 3 plots the decline in this average measure of adjusted productivity over time. On average, productivity declines by about 0.05% for firms that experience a negative β shock. Using revenues net of capital costs relative to a weighted bundle of labor and capital, this measure falls by approximately 0.1% on average.

The right graph of the Figure shows the evolution of profits for firms that are affected by a negative β shock. Upon the realization of the shock, profits increase as firms cut investments to reduce their scale while profits fall by about 1.5% in the long-run on average.

Figure 3: Capital Misallocation and Profits in Firms with Declining β



Notes: The Figure depicts the dynamic adjustments for productivity (left graph), defined as in (15), and profits (right graph) as averages across firms that experience a negative β shock over time. All variable means are indexed to pre-shock values. The dashed lines depict 95% confidence intervals.

General Equilibrium: We finally analyze the effects of changes in managerial incentives in general equilibrium. When the reform increases firms' demand for short-term capital goods, some parts of the within-firm misallocation of capital could be mitigated by increases in capital costs. Furthermore, when firms produce at higher marginal costs due to a sub-optimal capital mix, final-good prices might increase leading to lower consumer welfare. At the same time, demand shifts away from short-termist firms because consumers can substitute towards cheaper goods. To study these effects, we use the same sample of firms as before but endogenize factor markets and demand for final goods. In this extension, goods produced by the firms within each sector are combined into a CES bundle. The various sectoral bundles are then combined into an aggregate Cobb-Douglas final good. We assume that capital adjustment costs are labor costs and we clear the labor market by equating aggregate labor demand with a fixed labor endowment.[29] The demand shifter B now

29

becomes an endogenous equilibrium object and we use labor as the numéraire such that the wage rate is normalized to 1 and homogeneous across sectors. Formal details on the general equilibrium model are provided in Appendix B.2.[30]

In Table 9, we present the counterfactual effects of our simulated reform on a set of aggregate variables. The presented numbers are relative changes compared to the steady-state value before the reform. In the partial-equilibrium setting, the shock caused gaps in the marginal products of capital causing a drop in output, capital stocks and a relative shift in investment from long-term to short-term capital goods. These findings carry through to the general-equilibrium case. Due to the counteracting general-equilibrium forces, the effects are quantitatively smaller. Aggregate output drops by about 8 basis points. If we compare the change in aggregate capital stocks, we see that the general-equilibrium change is about one third smaller than the partial-equilibrium change: while the capital stock falls by 0.81% in general equilibrium, it falls by 1.1% in partial equilibrium. Furthermore, the reduction of total investments is somewhat smaller (-0.59%) than the drop in the overall capital stock as firms need to reinvest more frequently due to the shift in the capital mix away from more durable capital goods. This shift can also be observed in the larger decline in long-term investments compared to the decline in short-term investments. Lastly, the general-equilibrium exercise allows us to determine the effects of the reform on the aggregate price level of the final good and hence on the real wage and thus welfare in the economy. Here, we observe an increase in the price level of about 17 basis points, which translates to an equally-sized decline in the real wage caused by the reform.

5 Conclusion

In this paper, we analyze how managerial incentives affect the allocation of capital. We provide empirical evidence showing that firms systematically shift investment expenditures towards less durable assets in response to a shift in managerial pay towards more short-term incentives. To quantify the impact of managerial present bias on capital (mis)allocation, we calibrate a dynamic model of firm investments in which managers determine investment policies and face incentive

[30] We abstract from firm entry and exit and still assume managers' remuneration packages as exogenously given. As such, we denote this extension a pseudo-general-equilibrium framework.

Table 9: General-Equilibrium Effects: Aggregate Results from Counterfactual Reform

Variable	Change (%)	Variable	Change (%)
Output	-0.08	Price level	0.17
Long-term investment	-0.88	Short-term investment	-0.46
Long-term capital stock	-0.97	Short-term capital stock	-0.51
Overall investment	-0.59	Overall capital stock	-0.81

Notes: The Table shows the effects of the simulated reform on a set of aggregate variables. For each variable, the effect is measured as the percentage change of the steady-state value after the reform relative to the steady-state value before the reform.

contracts.

Our results indicate that changes in incentives away from motivating managers to maximize long-term firm values cause substantial economic distortions. Firms cut their investments into long-term assets and within-firm capital misallocation increases due to a mismatch in decision-makers' private marginal products of capital and social marginal products of capital, causing a fall in output, capital stocks, productivity and real wages. We conclude that corporate decision-makers' incentives are crucial for economic policy-making as managers respond very sensitively to changes in their incentives, which in turn affects economic outcomes.

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Appendix

Contents

A Empirical Appendix

A.1 Sample Selection

Our empirical sample is pooled from the 1,664 firms covered in both, Compustat and Execucomp over the sample period. From these, we exclude 700 firms that are either classified as inactive (in Compustat) or never reported any investment between the years 1995 and 2015 (neither in Compustat nor in FactSet). We then exclude 133 firms for which Compustat starts reporting financial information only after 2004 or for that coverage ends before 2006. This leaves our sample at 831 firms. After we exclude utilities, financial and public sector firms, we are left with around 699 firms. Depending on the choice of fixed effects, the sample size might slightly differ as some observations are absorbed by those.

A.2 Economic Significance: Calculating the Increase in Refinancing Costs

Table 4 reveals that for option-paying firms the average depreciation rate increased by 0.93 percentage points compared to non-option-paying firms. Assuming that the durability of the capital stock of non-option-paying firms was not affected by FAS 123R, we map this relative change to an absolute number. We compute the average pre-FAS-123R depreciation rate for option-paying firms, which is 18.10% in 2004. This rate converts into a durability of $2,016$ days ($\frac{1}{0.1810} \times 365$ days) for the capital stock. The FAS-123R-induced depreciation rate for option-paying firms is equal to 19.03% (18.10%+0.93%), which implies a durability for the firms' capital stock of 1,918 days. Therefore, FAS 123R decreased the durability of the capital stock by 98 days. Assuming an annual refinancing interest rate of 3%, this lower durability would be associated with an additional amount of interest payments of USD 8.05 for each USD 1,000 invested ($0.03 \times \frac{98}{365} \times$ USD $1,000$).

A.3 Robustness and Additional Results

This Appendix presents several robustness analyses and additional results.

Changing Incentives around the Reform: Columns (1) and (2) of Table A.1 show that executive compensation of firms that offered shifted away from equity around the reform. Columns (3) and (4) show that the increase in restricted stock was small and insignificant for treated firms relative to untreated firms. Furthermore, columns (5) and (6) use the pay-duration measure suggested by Gopalan et al. (2014) as outcome. Gopalan et al. (2014) Pay duration for executives in treated firms fell by around 2 months.

Firm Size and Other Ex-ante Differences: Table A.2 compares treated and untreated firms. Table A.3 includes additional interactions with firm size, using assets, employment or capital stocks as a proxy for the size of firms. Table A.4 includes additional interactions with the intangible investment share, the liquidity ratio, equity volatility or current CEO pay as these were significantly different ex ante between treatment- and control-group firms.

CEO Turnover: Table A.5 replicates estimates focusing on a subsample that includes only firms with a unique CEO to show that results are not determined by CEO-turnover events. Results indicate that the effect is even more pronounced when we exclude firms where CEO turnover occurred.

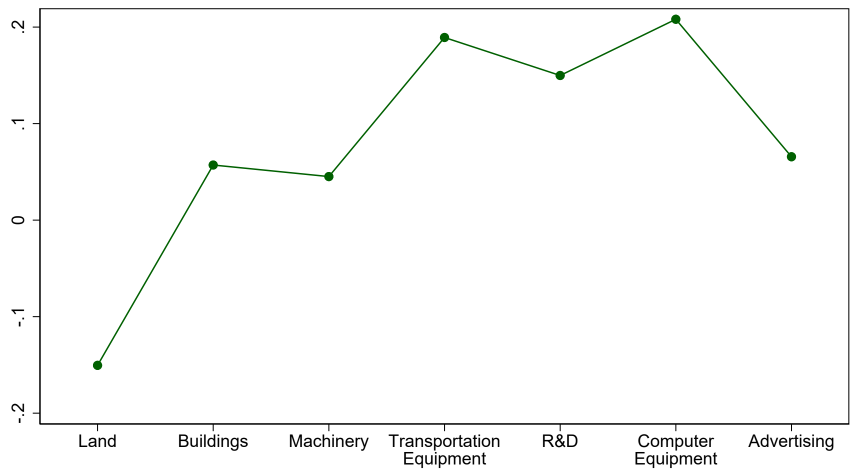
Measurement of Investments: Table A.6 shows robustness regarding the measurement of investments. It replicates our findings based on either investment rates or logarithmized investments or when missing investments are treated as 0 expenditures.

R&D Investment and Intangibles: Table A.7 shows robustness regarding the inclusion of R&D and intangibles as investment categories. It replicates results when either R&D investments are excluded or when we include interactions with a dummy that indicates intangible investment categories.

Using FAS123 as Instrument: Table A.8 shows results using the interaction between the dummy for unexercised options in 2004 and the FAS 123R timing dummy as an instrument for managerial equity ownership. The first stage coefficient confirms the expected reduction in managerial equity ownership with F-statistics of around 50 or higher. The second-stage results suggest a significant relation between lower equity ownership and a shift towards short-term investments.

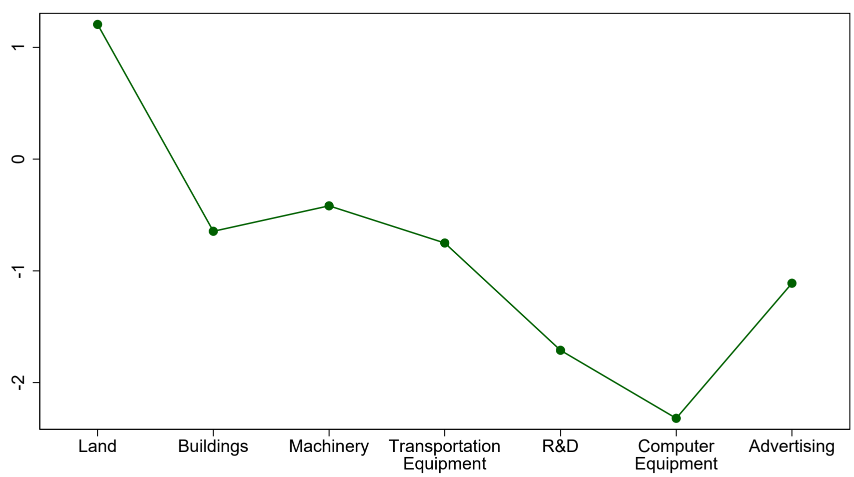
Structural Parameters: Table A.9 exploits time variation in the model-derived parameter β to study its effect on investment and firm-specific depreciation rates.

Figure A.1: Incentives and the Durability of Investments - By Category



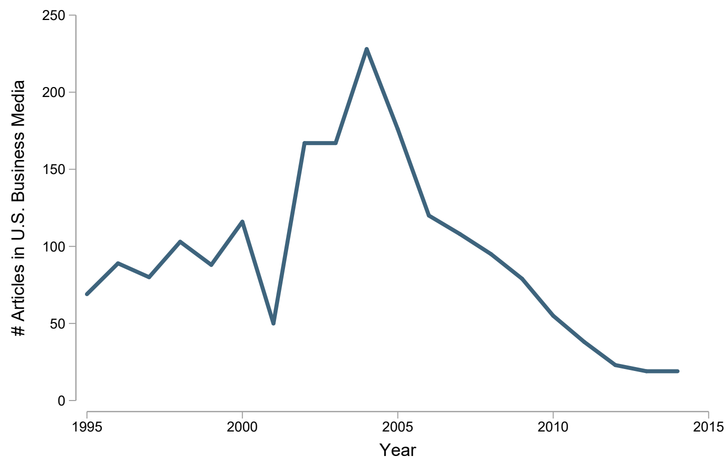
Notes: The Figure plots jointly estimated category-specific coefficients when investments are regressed on the interaction between an option dummy with a FAS123R-dummy and category dummies. The null hypothesis of coefficient equality across categories can be rejected at the 1%-level ($p < 0.001$).

Figure A.2: Equity Ownership and the Durability of Investments - By Category



Notes: The Figure plots jointly estimated category-specific associations between investment and managerial equity ownership. Fixed effects for firm-specific categories and years are included. The null hypothesis of coefficient equality across categories can be rejected at the 5%-level ($p = 0.015$).

Figure A.3: Media Coverage on FAS 123R over Time



Notes: The Figure plots the number of articles covering the reform in U.S. business media over time. The number of articles is defined as the number of items found searching for `((FAS OR Accounting Standard)) AND (manager OR Executive) AND (Equity OR Option OR Stock)` on the Nexis database, using the Financial Times, New York Times, Wall Street Journal, CNBC, USA Today and American Banker as sources.

Table A.1: FAS 123R Accounting Reform and the Structure of Incentives

	Non-Current Compensation		Restricted Stock		Duration	
	(1)	(2)	(3)	(4)	(5)	(6)
FAS123 x Option	-0.342	-0.363	0.202	0.0776	-0.161	-0.181
	(0.114)	(0.0918)	(0.290)	(0.259)	(0.0849)	(0.0995)
Total Compensation	1.718	1.629	1.026	0.905		
	(0.106)	(0.0550)	(0.193)	(0.166)		
Year FE	×	×	×	×	×	×
Firm FE	×	×	×	×	×	×
Observations	3,912	9,806	3,979	9,930	3,173	6,194
No. Firms	695	699	698	699	562	567
Sample Period	2002 - 2007	2000 - 2014	2002 - 2007	2000 - 2014	2002 - 2007	2000 - 2014

Notes: The Table reports the results on the relationship between the FAS 123R reform and the structure of managerial compensation. *Option-Dummy* is a dummy that indicates if any unexercised options are outstanding in 2004. *FAS123* takes value 0 for each year until 2005 and value 1 afterwards. *Non-current compensation* is the log of equity and equity-linked compensation (calculated as *TDC1 - TOTAL_CURR* in Compustat) and *Total Compensation* is the log of total compensation (*TDC1* in Compustat). *Restricted stock* is the inverse hyperbolic sine of restricted stock (*rstkgrnt* or *stock_awards_fv* in Compustat). *Duration* is the duration of executive compensation in years, computed as in Gopalan et al. (2014). Standard errors (reported in parentheses) are clustered at the firm-level.

Table A.2: Summary Statistics on Treated and Untreated Firms

Variable	Option-Paying (Treated, N=553)	Non-Option-Paying (Control, N=144)	t-test	p-value
Total Assets	8,153	7,491	0.29	0.77
Sales	7,512	7,145	0.16	0.87
Capital Stock	3,709	2,897	1.02	0.31
Employment	32.15	17.56	3.10	$<$**0.01**
Labor Productivity	115.4	98.9	1.44	0.15
Depreciation Rate	0.17	0.18	-1.35	0.18
Intangible Share	0.49	0.56	-2.01	**0.05**
Investment Rate	0.05	0.04	1.23	0.22
Leverage Ratio	0.20	0.19	0.19	0.85
Liquidity Ratio	0.15	0.21	-3.46	$<$**0.01**
Equity Volatility	0.34	0.40	-3.64	$<$**0.01**
Current CEO Compensation	1,929	1,538	2.05	**0.04**

Notes: A firm is considered as treated if it has unexercised stock options to its management in 2004. Summary statistics correspond to 2004 values. *Total Assets*, *Sales* and *Capital Stock* are denoted in millions USD, *Employment* is denoted in thousands. *Labor Productivity* is value added per employee in thousands USD (calculated as $(\text{SALE - COGS}) / \text{EMP})$. *Capital Stock* is obtained by summing up category-specific capital stocks for each firm, *Depreciation Rate* is the capital-stock weighted mean of category-specific depreciation rates for each firm. *Intangible Share* is the ratio of intangible investments (sum of advertising and R&D investments) to total investments. *Investment Rate* is capital expenditures (CAPX) relative to total assets (AT). The *Leverage Ratio* is defined as the ratio of total debt (sum of items DLC and DLTT) to total assets. The *Liquidity Ratio* equals the ratio of cash and short-term investments (CHE) to total assets. *Equity Volatility* is the annualized equity-return volatility, calculated as the standard deviation of daily stock returns multiplied by $\sqrt{252}$. Daily returns are calulated as $(\text{PRCCD} \times \text{TRFD} / \text{AJEXDI})$ relative to the previous day. *Current CEO Compensation* is the current compensation of the CEO in thousands USD (compensation excluding equity).

Table A.3: Robustness: Incentives and the Durability of Investments - Controlling for Firm Size

	Investments					
	(1)	(2)	(3)	(4)	(5)	(6)
Firm Size Measure:	*Employment*		*Assets*		*Capital Stock*	
Measure of Depreciation:	*Ordinal Rank*	*Depreciation Rate*	*Ordinal Rank*	*Depreciation Rate*	*Ordinal Rank*	*Depreciation Rate*
FAS123 × Option × Depr	0.0464	0.473	0.0477	0.503	0.0456	0.489
	(0.0201)	(0.191)	(0.0201)	(0.192)	(0.0200)	(0.190)
FAS123 × Depr	-0.0240	-0.386	0.0347	0.0674	0.00577	-0.116
	(0.0188)	(0.183)	(0.0353)	(0.342)	(0.0315)	(0.301)
FAS123 × Firm Size × Depr	-0.00685	-0.0194	-0.00984	-0.0676	-0.00655	-0.0477
	(0.00484)	(0.0460)	(0.00463)	(0.0443)	(0.00420)	(0.0395)
Category-Firm FE	×	×	×	×	×	×
Firm-Year FE	×	×	×	×	×	×
Observations	12,887	12,887	12,953	12,953	12,953	12,953
No. Firms	659	659	663	663	663	663
Sample Period	2002 - 2007	2002 - 2007	2002 - 2007	2002 - 2007	2002 - 2007	2002 - 2007

Notes: This Table reports the results on the relationship between managerial incentives and investment decisions. Value of total assets, capital stocks and number of employees are logarithmized and represent 2004 values. *Option-Dummy* is a dummy that indicates if any unexercised options are outstanding in 2004. *FAS123* takes value 0 for each year until 2005 and value 1 afterwards. *Depr* is the measure of depreciation, following an ordinal scale in columns 1, 3 and 5, and expressed in absolute depreciation rates in columns 2, 4 and 6. Standard errors (reported in parentheses) are clustered at the firm-level.

Table A.4: Robustness: Incentives and the Durability of Investments - Controlling for Other Firm Differences

	Investments							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Firm Control:	*Intangible Share*		*Liquidity Ratio*		*Equity Volatility*		*Current CEO Compensation*	
Measure of Depreciation:	*Ordinal Rank*	*Depreciation Rate*	*Ordinal Rank*	*Depreciation Rate*	*Ordinal Rank*	*Depreciation Rate*	*Ordinal Rank*	*Depreciation Rate*
FAS123 × Option × Depr	0.0409	0.453	0.0392	0.398	0.0463	0.483	0.0479	0.483
	(0.0201)	(0.189)	(0.0201)	(0.188)	(0.0206)	(0.196)	(0.0209)	(0.200)
FAS123 × Depr	-0.0254	-0.324	-0.0275	-0.229	-0.0618	-0.562	0.0375	-0.163
	(0.0231)	(0.232)	(0.0207)	(0.195)	(0.0300)	(0.288)	(0.0790)	(0.748)
FAS123 × Control × Depr	-0.0192	-0.168	-0.0380	-0.849	0.0692	0.378	-0.0107	-0.0377
	(0.0265)	(0.255)	(0.0508)	(0.484)	(0.0587)	(0.548)	(0.0113)	(0.107)
Category-Firm FE	×	×	×	×	×	×	×	×
Firm-Year FE	×	×	×	×	×	×	×	×
Observations	12,933	12,933	12,953	12,953	12,953	12,953	12,902	12,902
No. Firms	661	661	663	663	663	663	661	661
Sample Period	2002 - 2007	2002 - 2007	2002 - 2007	2002 - 2007				

Notes: This Table reports the results on the relationship between managerial incentives and investment decisions. *Equity Volatility* is the annualized equity-return volatility in 2004, calculated as the standard deviation of daily stock returns multiplied by $\sqrt{252}$. *Current CEO Compensation* is the logarithmized current compensation of the CEO (compensation excluding equity) in 2004. *Option-Dummy* is a dummy that indicates if any any unexercised options are outstanding in 2004. *FAS123* takes value 0 for each year until 2005 and value 1 afterwards. *Depr* is the measure of depreciation, following an ordinal scale in columns 1, 3, 5 and 7 and expressed in absolute depreciation rates in columns 2, 4, 6 and 8. Standard errors (reported in parentheses) are clustered at the firm-level.

Table A.5: Robustness: Incentives and the Durability of Investments - CEO Turnover

	Investments				
	(1)	(2)	(3)	(4)	(5)
Measure of Depreciation:	*Depreciation Rate*				
FAS123 × Option × Depr	1.331	0.823	0.855	0.393	0.779
	(0.379)	(0.345)	(0.309)	(0.259)	(0.382)
FAS123 × Depr	-0.873	-0.515	-0.816	-0.488	-0.872
	(0.320)	(0.320)	(0.247)	(0.226)	(0.320)
Option × Depr	-1.109		-1.195		-153.1
	(0.474)		(0.481)		(60.33)
Measure of Depreciation:	*Ordinal Rank*				
FAS123 × Option × Depr	0.125	0.0714	0.0863	0.0392	0.0513
	(0.0356)	(0.0309)	(0.0331)	(0.0264)	(0.0367)
FAS123 × Depr	-0.0613	-0.0290	-0.0778	-0.0447	-0.0611
	(0.0305)	(0.0282)	(0.0280)	(0.0230)	(0.0305)
Option × Depr	-0.120		-0.128		-20.48
	(0.0528)		(0.0516)		(6.373)
Category FE	×		×		×
Category-Firm FE		×		×	
Firm-Year FE	×	×	×	×	×
Trend					×
Observations	14,810	14,779	5,919	5,851	14,810
No. Firms	292	291	286	285	292
Sample Period	2000 - 2014	2000 - 2014	2002 - 2007	2002 - 2007	2000 - 2014

Notes: The Table reports results on the relationship between managerial incentives and investment decisions. There are only firms included which have been run by the same CEO between 2002 and 2007. *Option* is a dummy that indicates if any unexercised options are outstanding in 2004. *FAS123* takes value 0 for each year until 2005 and value 1 afterwards. *Depr* is the measure of depreciation, expressed in absolute depreciation rates in the upper panel and following an ordinal scale in the lower panel. Column 5 additionally includes a treatment-specific linear trend: Trend × Option × Depr. Standard errors (reported in parentheses) are clustered at the firm-level.

Table A.6: Robustness: Incentives and the Durability of Investments - Alternative Transformation of the Investment Variable

	Investments							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Transformation of Outcome:	*Investment Rate*		*Logarithms*		$Ln($*Investment+1*$)$		*Missings as 0s*	
FAS123 × Option × Depr	0.00542	0.0619	0.0934	1.013	0.0524	0.623	0.0404	0.430
	(0.00219)	(0.0209)	(0.0274)	(0.277)	(0.0188)	(0.196)	(0.0225)	(0.220)
FAS123 × Depr	-0.00116	-0.0149	-0.0478	-0.742	-0.00900	-0.293	0.0554	0.332
	(0.00194)	(0.0182)	(0.0255)	(0.259)	(0.0170)	(0.178)	(0.0198)	(0.193)
Category-Firm FE	×	×	×	×	×	×	×	×
Firm-Year FE	×	×	×	×	×	×	×	×
Observations	31,074	31,074	30,384	30,384	32,953	32,953	73,724	73,724
No. Firms	680	680	681	681	683	683	725	725
Sample Period	2000 - 2014	2000 - 2014	2000 - 2014	2000 - 2014	2000 - 2014	2000 - 2014	2000 - 2014	2000 - 2014

Notes: This Table reports the results on the relationship between managerial incentives and investment decisions. The following transformation applies to the dependent variable y: $x/$capital stock for columns 1 – 2, $y = ln(x)$ for columns 3 – 4, $y = ln(x+1)$ for columns 5 – 6 and missings are treated as 0s for columns 7 – 8. *Option* is a dummy that indicates if any unexercised options are outstanding in 2004. *FAS123* takes value 0 for each year until 2005 and value 1 afterwards. *Depr* is the measure of depreciation, following an ordinal scale in odd columns and expressed in absolute depreciation rates in even columns. Standard errors (reported in parentheses) are clustered at the firm-level.

Table A.7: Robustness: Incentives and the Durability of Investments - Assessing the Role of R&D and Intangibles

	Investments					
	(1)	(2)	(3)	(4)	(5)	(6)
	Omitting R&D			*Controlling for Intangibles*		
FAS123 × Option × Depr	0.978	0.711	0.704	0.787	0.674	0.557
	(0.250)	(0.224)	(0.242)	(0.352)	(0.280)	(0.295)
Option × Depr	-0.363		-0.418	0.758		0.683
	(0.331)		(0.340)	(0.696)		(0.719)
FAS123 × Depr	-0.865	-0.417	-0.792	-0.754	-0.531	-0.606
	(0.215)	(0.204)	(0.211)	(0.311)	(0.258)	(0.255)
Category FE	×		×	×		×
Category-Year FE		×			×	
Firm-Year FE	×	×	×	×	×	×
Observations	25,726	25,645	10,230	32,947	32,875	13,097
No. Firms	674	669	657	681	677	666
Sample Period	2000 - 2014	2000 - 2014	2002 - 2007	2000 - 2014	2000 - 2014	2002 - 2007

Notes: The Table reports the results on the relationship between managerial incentives and investment decisions. Columns 1 to 3 omit R&D investments and columns 4 - 6 additionally control for interactions between a dummy that indicates intangible investment categories (R&D and advertising), *FAS123* and *Option-Dummy*. *Option* is a dummy that indicates if any unexercised options are outstanding in 2004. *FAS123* takes value 0 for each year until 2005 and value 1 afterwards. *Depr* is the measure of depreciation expressed in absolute depreciation rates. Standard errors (reported in parentheses) are clustered at the firm-level.

Table A.8: Equity Ownership and the Durability of Investments - 2SLS using FAS 123R

	Investments	
	(1)	(2)
Measure of Depreciation:	*Ordinal Rank*	*Dep. Rate*
Equity Share × Depr	-2.840	-18.87
	(0.736)	(6.846)
1st Stage:		
FAS123 × Option × Depr	-0.0139	-0.0144
	(0.00168)	(0.00204)
Kleibergen-Paap F-Statistic	68.3	49.7
Category-Firm FE	×	×
Firm-Year FE	×	×
Observations	28,611	28,611
No. Firms	649	649
Sample Period	2000 - 2014	2000 - 2014

Notes: The Table reports the results on the relationship between managerial equity ownership and investment decisions based on 2SLS estimates. *Equity Ownership* is the CEO's ownership share. *Depr* is the measure of depreciation, following an ordinal scale in column 1 and expressed in absolute depreciation rates in column 2. *Equity Share × Depr* is instrumented with *FAS123 × Option × Depr*. Standard errors (reported in parentheses) are clustered at the firm-level.

Table A.9: Beta and the Durability of Investments/Capital Stock Depreciation

	Investments				Weighted Avg. Depr. Rate
	(1)	(2)	(3)	(4)	(5)
Model	OLS		IV		OLS
			1st Stage	*2nd Stage*	
$(1-\beta)\times$ Depr	0.281	0.091			
	(0.081)	(0.036)			
FAS123 $\times$ Option $\times$ Depr			0.046		
			(0.004)		
$\widehat{(1-\beta)\times}$ Depr				0.862	
				(0.212)	
$(1-\beta)$					0.015
					(0.006)
Category FE	$\times$				
Category-Year FE		$\times$	$\times$	$\times$	
Firm-Year FE	$\times$	$\times$	$\times$	$\times$	
Firm FE					$\times$
Year FE					$\times$
Observations	28,695	28,611	28,611	28,611	8,614
No. Firms	655	649	649	649	672
Sample Period	2000 - 2014	2000 - 2014	2000 - 2014	2000 - 2014	2000 - 2014
Kleibergen-Paap F-Statistic			113.20		

Notes: The Table reports the results on the relationship between the model-specific incentive measure β and the durability of investments, respectively the depreciation of firms' capital stock. The calculation of β follows Equation (12), details on the computation can be found in Appendix C.1. *Depr* is the measure of depreciation, following an ordinal scale. *Option* is a dummy that indicates if any unexercised options are outstanding in 2004. *FAS123* takes value 0 for each year until 2005 and value 1 afterwards. In columns 1 and 2, we investigate the relationship between the firm-specific β and the durability of investments. In column 4, we address endogeneity concerns related to β by instrumenting $(1-\beta)$ $\times$ *Depr* with *FAS123* $\times$ *Option-Dummy* $\times$ *Depr*. First-stage results are given in column 3. Column 5 estimates the effect of β on the capital stock depreciation by taking a firm-specific capital-stock-weighted depreciation rate as dependent variable. Standard errors (reported in parentheses) are clustered at the firm-level.

Table A.10: Incentives and Capital Stocks

	Capital Stocks				
	(1)	(2)	(3)	(4)	(5)
Measure of Depreciation:			*Depreciation Rate*		
FAS123 × Option × Depr	0.790	0.513	0.477	0.220	1.166
	(0.287)	(0.226)	(0.238)	(0.170)	(0.284)
FAS123 × Depr	-1.112	-0.634	-0.504	-0.164	-1.112
	(0.265)	(0.214)	(0.220)	(0.163)	(0.265)
Option × Depr	-0.623		-0.603		103.5
	(0.349)		(0.355)		(27.17)
Measure of Depreciation:			*Ordinal Rank*		
FAS123 × Option × Depr	0.0621	0.0416	0.0384	0.0224	0.0852
	(0.0264)	(0.0193)	(0.0216)	(0.0138)	(0.0262)
FAS123 × Depr	-0.0787	-0.0387	-0.0355	-0.0109	-0.0787
	(0.0246)	(0.0182)	(0.0201)	(0.0129)	(0.0246)
Option × Depr	-0.0622		-0.0622		6.311
	(0.0337)		(0.0339)		(2.412)
Category FE	×		×		×
Category-Firm FE		×		×	
Firm-Year FE	×	×	×	×	×
Trend					×
Observations	36,765	36,694	14,640	14,532	36,765
No. Firms	690	684	670	661	690
Sample Period	2000 - 2014	2000 - 2014	2002 - 2007	2002 - 2007	2000 - 2014

Notes: The Table reports results on the relationship between managerial incentives and capital stocks. *Option* is a dummy that indicates if any unexercised options are outstanding in 2004. *FAS123* takes value 0 for each year until 2005 and value 1 afterwards. *Depr* is the measure of depreciation, expressed in absolute depreciation rates in the upper panel and following an ordinal scale in the lower panel. Column 5 additionally includes a treatment-specific linear trend: Trend × Option × Depr. Standard errors (reported in parentheses) are clustered at the firm-level.

B Theoretical Appendix

B.1 Derivation of Managers' Optimal Behavior

Since we are interested in a symmetric equilibrium, we denote the policy function for capital as $\mathcal{K}(\mathbf{K},\xi)$, i.e. if manager t follows this strategy profile, they will set $\mathbf{K}_{t+1} = \mathcal{K}(\mathbf{K}_t,\xi)$ when faced with a predetermined capital stock K_t. Here ξ is a simple vector collecting the parameters of the model: $\xi = (a,b,Z,\nu,\gamma,\delta_l,\delta_s,\varphi,\beta,\theta,w)$. Likewise, $\mathcal{N}(\mathbf{K},\xi)$ denotes the policy function for N_t. Note that $\mathcal{K}(\cdot)$ is a vector-valued function with two outputs (one for each capital good), which in turn we denote by $\mathcal{K}_j(\mathbf{K},\xi), j = l,s$. In particular, we denote

$$\mathbf{K}_{t+1} = \mathcal{K}(\mathbf{K}_t,\xi) := \begin{bmatrix} \mathcal{K}_l(\mathbf{K}_t,\xi) \\ \mathcal{K}_s(\mathbf{K}_t,\xi) \end{bmatrix}.$$

Under this restriction, we can represent manager t's maximization problem in a recursive way. Here, to save on notation, we drop time indices and follow a common convention in the literature: e.g., we denote by K_j the value of K_{jt} at some arbitrary point in time and by K'_j the value of $K_{j,t+1}$ for $j = l,s$. One can then use a similar approach for all other variables, in particular the current capital mix as $\mathbf{K} = [K_l\ K_s]'$ and the capital mix one period later as $\mathbf{K}'$. First, we obtain a function for the period-profits:

$$\pi(\mathbf{K},\mathbf{K}',N,\xi) = Z^{1-a-b}\left(K_l^{\nu}K_s^{1-\nu}\right)^a N^b - \sum_{j\in\{l,s\}}\left[\frac{\gamma}{2}\left(\frac{K'_j}{K_j}-1\right)^2 K_j + K'_j - (1-\delta_j)K_j\right] - wN \tag{B.1}$$

Next, the value of equity $E(\cdot)$ can be decomposed into current profits and a continuation value, denoted by the function $V(\mathbf{K}',\xi)$:

$$E(\mathbf{K},\mathbf{K}',N,\xi) = \pi(\mathbf{K},\mathbf{K}',N,\xi) + \theta V(\mathbf{K}',\xi)$$

where this continuation value is given by

$$\begin{aligned} V(\mathbf{K},\xi) &= E(\mathbf{K},\mathcal{K}(\mathbf{K},\xi),\mathcal{N}(\mathbf{K},\xi),\xi) \\ &= \pi(\mathbf{K},\mathcal{K}(\mathbf{K},\xi),\mathcal{N}(\mathbf{K},\xi),\xi) + \theta V(\mathcal{K}(\mathbf{K},\xi),\xi) \end{aligned}$$

As a result, the value of the manager's remuneration is also a function of their decision according to:

$$\Gamma(\mathbf{K},\mathbf{K}',N,\xi) = \varphi\left(\pi(\mathbf{K},\mathbf{K}',N,\xi) + \beta\theta V(\mathbf{K}',\xi)\right)$$

Using these functional definitions, we can express a particular manager's optimized payoff from

(13) as

$$\Gamma^*(\mathbf{K},\xi) := \max_{(\mathbf{K}',N)} \{\Gamma(\mathbf{K},\mathbf{K}',N,\xi)\} \tag{B.2}$$

And similarly, the policy functions for the capital mix and labor are given by

$$(\mathcal{K}(\mathbf{K},\xi),\mathcal{N}(\mathbf{K},\xi)) := \arg\max_{(\mathbf{K}',N)} \{\Gamma(\mathbf{K},\mathbf{K}',N,\xi)\}$$

These policy function thus need to satisfy a set of optimality conditions. In particular, the policy function for labor can be derived analytically as

$$\mathcal{N}(\mathbf{K},\xi) = \left(\frac{bZ^{1-a-b}\left(K_l^{\nu}K_s^{1-\nu}\right)^a}{w}\right)^{\frac{1}{1-b}}. \tag{B.3}$$

This directly follows from the first-order condition

$$\frac{\partial}{\partial N}\Gamma(\cdot) \overset{!}{=} 0 \quad \Leftrightarrow \quad \varphi\frac{\partial}{\partial N}\pi(\cdot) \overset{!}{=} 0 \Leftrightarrow \quad \frac{\partial}{\partial N}\pi(\cdot) \overset{!}{=} 0,$$

whereas it is generally impossible to solve for analytical policy functions for the capital goods. At most, the following self-referencing characterization is possible:

$$\begin{aligned}\mathcal{K}_j(\mathbf{K},\xi) = \Bigg\{ K_j' \Bigg|\ & 0 = \frac{\partial}{\partial K_j'}\pi(\mathbf{K},\mathbf{K}',N,\xi) + \beta\theta\frac{\partial}{\partial K_j}\pi(\mathbf{K}',\mathcal{K}(\mathbf{K}',\xi),\mathcal{N}(\mathbf{K}',\xi),\xi) \\ & + \theta(1-\beta)\sum_{k=l,s}\frac{\partial}{\partial K_j}\mathcal{K}_k(\mathbf{K}',\xi)\frac{\partial}{\partial K_k}V(\mathcal{K}(\mathbf{K}'),\xi)\Bigg\}\end{aligned} \tag{B.4}$$

To derive this condition, first note that the first-order condition can be stated as

$$\begin{aligned}&\frac{\partial}{\partial K_j'}\Gamma(\cdot) \overset{!}{=} 0 \\ \Leftrightarrow\ &\varphi\left(\frac{\partial}{\partial K_j}\pi(\cdot) + \beta\theta\frac{\partial}{\partial K_j}V(\cdot)\right) \overset{!}{=} 0\end{aligned} \tag{B.5}$$

The envelope condition defining $\frac{\partial}{\partial K_j}V(\cdot)$ is given by

$$\begin{aligned}\frac{\partial}{\partial K_j}V(\cdot) = &\frac{\partial}{\partial K_j}E(\mathbf{K},\mathcal{K}(\mathbf{K},\xi),\mathcal{N}(\mathbf{K},\xi),\xi) + \sum_{k=l,s}\frac{\partial}{\partial K_j}\mathcal{K}_k(\mathbf{K},\xi)\frac{\partial}{\partial K'_k}E(\mathbf{K},\mathcal{K}(\mathbf{K},\xi),\mathcal{N}(\mathbf{K},\xi),\xi) \\ &+ \frac{\partial}{\partial K_j}\mathcal{N}(\mathbf{K},\xi)\frac{\partial}{\partial N}E(\mathbf{K},\mathcal{K}(\mathbf{K},\xi),\mathcal{N}(\mathbf{K},\xi),\xi) \\ = &\frac{\partial}{\partial K_j}\pi(\mathbf{K},\mathcal{K}(\mathbf{K},\xi),\mathcal{N}(\mathbf{K},\xi),\xi) \\ &+ \sum_{k=l,s}\frac{\partial}{\partial K_j}\mathcal{K}_k(\mathbf{K},\xi)\left[\frac{\partial}{\partial K'_k}\pi(\mathbf{K},\mathcal{K}(\mathbf{K},\xi),\mathcal{N}(\mathbf{K},\xi),\xi) + \theta\frac{\partial}{\partial K'_k}V(\mathcal{K}(\mathbf{K},\xi)\right] \\ &+ \frac{\partial}{\partial K_j}\mathcal{N}(\mathbf{K},\xi)\frac{\partial}{\partial N}\pi(\mathbf{K},\mathcal{K}(\mathbf{K},\xi),\mathcal{N}(\mathbf{K},\xi),\xi)\end{aligned}$$

From optimal labor demand, it follows that $\frac{\partial}{\partial N}\pi(\cdot) = 0$ such that this simplifies to

$$\begin{aligned}\frac{\partial}{\partial K_j}V(\cdot) = &\frac{\partial}{\partial K_j}\pi(\mathbf{K},\mathcal{K}(\mathbf{K},\xi),\mathcal{N}(\mathbf{K},\xi),\xi) \\ &+ \sum_{k=l,s}\frac{\partial}{\partial K_j}\mathcal{K}_k(\mathbf{K},\xi)\left[\frac{\partial}{\partial K'_k}\pi(\mathbf{K},\mathcal{K}(\mathbf{K},\xi),\mathcal{N}(\mathbf{K},\xi),\xi) + \theta\frac{\partial}{\partial K'_k}V(\mathcal{K}(\mathbf{K},\xi)\right] \qquad \text{(B.6)}\end{aligned}$$

Inserting equation (B.5) on the left-hand side and –iterated by one period– on the right-hand side of (B.6) gives equation (B.4).

Finally, by re-inserting time indices and suppressing functional dependencies, we can reformulate equations (B.3) and (B.4) to obtain labor demand and (14) in the main text.

B.2 Pseudo-General-Equilibrium Effects

To test the mechanism for robustness to general-equilibrium effects, we reuse the firm sample from our quantitative exercise (including the relevant parameters and β-transitions), and assume that the $\mathcal{N}_f = 1,000$ firms inhabit one single economy, divided into the $S = 13$ sectors from Table 7. Each sector is denoted by $s = 1, \dots, S$, each firm by $f = 1, \dots, \mathcal{N}_f$. For future reference, we define two mappings that link firms and their industries: firm f's sector is given by $s_f = 1, \dots, S$ and the sector s is composed of a set of firms $F_s = \{f = 1, \dots, \mathcal{N}_f | s_f = s\}$.

B.2.1 Demand

As before, we abstract from aggregate dynamics and we are only interested in the change of steady-state variables.[31] Also, as in the previous section, we use the notation x to represent a variable x's value in the current period and x' (x'') for the value of x one period (two periods) ahead.

[31]Solving the model with aggregate dynamics would, of course, be feasible, but it would be rather complicated (cf., e.g. Krusell and Smith, 1998) and it is not clear what this would add to the analysis at hand.

A competitive final goods firm produces a final consumption good $\mathcal{Q}$ from the sectoral inputs Q_s according to the Cobb-Douglas production function

$$\mathcal{Q} = \prod_{s=1}^{S} \mathcal{Q}_s^{\psi_s}.$$

Here, the ψ_s are calculated from Table 7 as the respective shares of value added that sector s contributes to total value added such that they satisfy $\psi_s \in (0,1)$ and $\sum_{s=1}^{S} \psi_s = 1$.

The corresponding aggregate price-level is thus given by

$$\mathcal{P} = \prod_{s=1}^{S} \left(\frac{\mathcal{P}_s}{\psi_s} \right)^{\psi_s}, \tag{B.7}$$

where $\mathcal{P}_s$ denote sectoral price levels. Following standard logic, each sector thus faces a demand curve

$$\mathcal{Q}_s = \frac{\psi_s \mathcal{P} \mathcal{Q}}{\mathcal{P}_s}. \tag{B.8}$$

The sectoral goods are a CES-aggregate of the individual firms' outputs Q_f according to

$$\mathcal{Q}_s = \left(\sum_{f \in F_s} Q_f^{\frac{\varepsilon_s - 1}{\varepsilon_s}} \right)^{\frac{\varepsilon_s}{\varepsilon_s - 1}}. \tag{B.9}$$

Here, the ε_s directly follow from our calibration exercise above. We assume that firms engage in monopolistic competition. The corresponding sectoral price level based on firms' prices P_f is thus

$$\mathcal{P}_s = \left(\sum_{f \in F_s} P_f^{1-\varepsilon_s} \right)^{\frac{1}{1-\varepsilon_s}}. \tag{B.10}$$

Consequently each firm f in sector s faces the following demand:

$$Q_f = P_f^{-\varepsilon_s} \mathcal{P}_s^{\varepsilon_s} \mathcal{Q}_s. \tag{B.11}$$

We can now deduce that in each sector, the demand shifter is given by

$$B_s = \mathcal{P}_s^{\varepsilon_s} \mathcal{Q}_s.$$

This links firms on product markets while we also need to link firms' input usage K_{lf}, K_{sf} and N_f to factor markets.

B.2.2 Firm Behavior

The problem of the firm is still the same as in the partial-equilibrium setup. We only need to add the respective firm and industry subscripts to the various variables in equations (4)–(14).

For concreteness, we restate these here, dropping time indices and adding subscripts f and s: At a sectoral level, we have the following parameters:

$$a_s = \alpha_s \frac{\varepsilon_s - 1}{\varepsilon_s} \tag{B.12}$$

$$b_s = (1-\alpha_s)\frac{\varepsilon_s - 1}{\varepsilon_s} \tag{B.13}$$

In addition, the following relations characterize each firm's behavior:

$$Q_f = Z_f \left(K_{lf}^{\nu_s} K_{sf}^{1-\nu_s}\right)^{\alpha_s} N_f^{1-\alpha_s} \tag{B.14}$$

$$Q_f = B_s P_f^{-\varepsilon_s} \tag{B.15}$$

$$R_f = P_f Q_f \tag{B.16}$$

$$= X_f^{1-a_s-b_s}\left(K_{lf}^{\nu_s} K_{sf}^{1-\nu_s}\right)^{a_s} N_f^{b_s} \tag{B.17}$$

$$C_f^K = \sum_{j\in l,s}\left[\gamma\left(\frac{K'_{jf}}{K_{jf}} - 1\right)^2 K_{jf} + \left(K'_{jf} - (1-\delta_{js})K_{jf}\right)\right] \tag{B.18}$$

$$\Pi_f = R_f - C_f^K - w_s N_f \tag{B.19}$$

$$E_f = (1-\eta_{b,f})\Pi_f + \frac{1}{1+r}\mathbb{E}\left\{(1-\eta_{e,f})E'_f\right\} \tag{B.20}$$

$$\Gamma_f = \eta_{b,f}\Pi_f + \eta_{e,f}E_f \tag{B.21}$$

$$\varphi_f := \eta_{b,f} + \eta_{e,f}(1-\eta_{b,f}), \tag{B.22}$$

$$\beta_f := \frac{\eta_{e,f}(1-\eta_{b,f})}{\eta_{b,f} + \eta_{e,f}(1-\eta_{b,f})}, \tag{B.23}$$

$$\theta_f := \frac{1-\eta_{e,f}}{1+r} \tag{B.24}$$

$$N_f = \left(\frac{b_s X_f^{1-a_s-b_s}\left(K_{lf}^{\nu_s} K_{sf}^{1-\nu_s}\right)^{a_s}}{w_s}\right)^{\frac{1}{1-b_s}} \tag{B.25}$$

$$0 = \frac{\partial \Pi_f}{\partial K'_{jf}} + \beta_f\theta_f \frac{\partial \Pi'_f}{\partial K'_{jf}} + \theta_f(1-\beta_f)\sum_{k=l,s}\frac{\partial K''_{kf}}{\partial K'_{jf}}\frac{\partial}{\partial K''_{kf}} V_f(\mathbf{K}''_f, \xi'_s) \tag{B.26}$$

Note that now, the continuation value $V_f(\cdot)$ also depends on ξ_s, which is a vector containing the sector-wide and aggregate variables, i.e. $\xi_s = (B_s, w_s, r)$. $V_f(\cdot)$ is now given by

$$V_f(\mathbf{K}_f, \xi_s) := \Pi_f + \theta_f V_f(\mathbf{K}'_f, \xi'_s).$$

B.2.3 Factor Markets

Regarding the labor market, we deviate from the partial-equilibrium calibration before and assume a fixed homogeneous labor supply per household $\bar{N}$ which we treat as numéraire. This means the nominal wage across industries is fixed at $w_s = w = 1$ and the real wage is given by

$$w_{real} = \frac{w}{\mathcal{P}} = \frac{1}{\mathcal{P}}.$$

Since we assume that capital is owned by the firm and there are capital adjustment costs, we need an assumption how this investment is produced. For simplicity, we assume that capital goods are produced using only labor as an input and that the adjustment of capital goods also only requires labor as an input.[32]

I.e., the overall labor demand of firm f is given by

$$\bar{N}_f = N_f + \sum_{j \in \{l,s\}} I_{jf} + \gamma \left(\frac{K'_{jf}}{K_{jf}} - 1 \right)^2 K_{jf}, \tag{B.27}$$

where $I_{jf} = K'_{jf} - (1 - \delta_{js}) K_{jf}$ is the firm's gross investment in capital goods of type j.

B.2.4 Equilibrium

The economy is inhabited by a continuum of ex-ante homogeneous households (of measure 1). In every period, each household is endowed with $\bar{N} = 1$ units of labor that is inelastically offered on a competitive labor market in order to generate income w. Households are assumed to hold equity only indirectly via a competitive mutual fund. In each period, a single household ('manager') is randomly chosen to manage any given firm f, for which they receive the corresponding compensation Γ_f. We assume that managers neglect the effects that their individual decisions have on the mutual fund and – as before – we assume they do not anticipate to manage the firm in the future. We further assume time-separable, homothetic preferences with respect to consumption of a final good, as well as complete markets. This means we do not need to track the distribution of wealth and income to infer aggregate demand dynamics. On a related note, we do not impose any restrictions on how households distribute the Γ_f. In particular, it could be that managers just amass more wealth or that they use an insurance mechanism to distribute managers' income across all households.

[32]One could, of course, also assume that investment goods are produced using the final good, which would allow for input-output relationships to become important. For the sake of simplicity and comparability to the partial-equilibrium setup, we abstract from that. A side benefit is that this way, since both q_l, q_s and w are fixed, the firm is really only linked to the aggregate economy via the demand shifter B_s. This simplifies calculations a lot because the firm's operations scale one-for-one with the the demand shifter. Hence, when solving the model, each firm's problem has to be solved exactly once, and then its chosen quantities only need to be rescaled in order to guarantee market clearing in the aggregate.

For aggregate consumption C in any steady state, we thus end up with a simple relationship: all labor income $w \cdot 1$, managers' remuneration Γ_f and the remaining dividends of firms $\Pi_f - \Gamma_f$ (where Π_f is the operating profit of firm f) are used to fund final consumption. Hence, we have

$$C = \sum_{f=1}^{\mathcal{N}_f} \left[\Gamma_f + (\Pi_f - \Gamma_f)\right] + w = \sum_{f=1}^{\mathcal{N}_f} \Pi_f + w.$$

Since we treat labor as numéraire, this becomes

$$C = \sum_{f=1}^{\mathcal{N}_f} \Pi_f + 1. \tag{B.28}$$

To close the model, we impose market clearing on both, goods and labor markets which implies

$$C = \mathcal{Q} \tag{B.29}$$

$$1 = \sum_{f=1}^{\mathcal{N}_f} \bar{N}_f. \tag{B.30}$$

Limitations: Before moving on, it is important to note a few caveats in our general-equilibrium analysis. We abstract here from firm entry or exit, endogenous technological change and input-output relationships which all could certainly alter some aspects of the quantification. We also still treat the remuneration packages as exogenous. However, since we are interested in the effects of changes in remuneration packages per se, we thus consider this to be a reasonable assumption

B.2.5 Experiment

The experiment we conduct in this general-equilibrium setting is very much akin to the one reported for the partial-equilibrium case in the main text. The firms have the same parameterization as before. The only differences are that $w = 1$ for all firms and that the sectoral demand shifter is endogenous and adapts to ensure that the labor-market-clearing condition holds. Since we abstract from aggregate dynamics here (otherwise the solution algorithm would be a lot more involved), we focus on a steady-state comparison taking the observed changes due to FAS 123R as a permanent 'shock'.

B.2.6 Discussion

The quantified aggregate output drop equals 8 basis points in the general-equilibrium setting, compared to the 50 basis points in the partial-equilibrium setting. Besides differences in sectoral wages, the partial-equilibrium analyses plot means of normalized firm values which cannot be used for the aggregate adjustments in general equilibrium since here, the size differences across firms matter as well. Thus, the behavior of the normalized aggregate variables presented in Table 9 rather resembles the one of a normalized mean *across* firms in the economy. To isolate the general-equilibrium feedback, we therefore also consider a scenario, where we shock the βs but keep B constant such that we are still in a partial-equilibrium setting but with homogeneous wages fixed at 1. If we apply this to our sample and consider the same output measure as in the partial-equilibrium setting from before, firms' output shrinks by 0.61% on average which is substantially closer to the 0.50% obtained in the partial-equilibrium analysis with sectoral wage data. In general equilibrium, this overall effect on average firm output is then mitigated in absolute terms due to factor-market competition. Here, firms' output shrinks on average by 0.29% due to the reform. In contrast, if we take size differences across firms into account, the (fictitious) average firm sees its output decrease by 0.42% in the partial-equilibrium setting, whereas the average firm in general equilibrium has an output decrease of 12 basis points. The general-equilibrium effects at the aggregate level are thus broadly in line with the behavior of the fictitious average firm that we studied in partial equilibrium. However, since consumers substitute demand away from short-termist firms, the effect on aggregate output is about one third smaller (8 versus 12 basis points) compared to the output change for the average firm.

C Parameterization and Solution Method

C.1 Remuneration Package

As we have derived in Section 3, the parameter β is a structural parameter which is determined solely by the bonus share η^b and the equity share η^e (see Equation (12)). Both parameters can be directly inferred from the data relying on different sources which have been widely used in the literature.

For η^b, we directly obtain the amount of bonus from Execucomp. Furthermore, due to a change in the reporting requirements for executive compensation after December 2006 we add the amount of non-equity incentive compensation to the bonus, which can be found in the *Plan-Based Awards* (*PBA*) file. This reclassification of bonuses is stressed by Hayes et al. (2012) and we follow their approach. In a next step we scale the amount of bonus payments with the sales of the firm (obtained from Compustat), i.e. $\eta^b = \frac{\text{Bonus+Non-eq-Targ}}{\text{Sales}}$.

For the equity share η^e, we rely on data on the manager's firm-related wealth provided by Coles et al. (2006) and Core and Guay (2002), which we divide by the total market capitalization of the respective firm (obtained from Compustat), i.e. $\eta^e = \frac{\text{Firm-related Wealth}}{\text{Market Capitalization}}$.

We winsorize each parameter $\eta_{b/e}$ at the top and bottom 1%. In a final step, we calculate β by applying Equation (12).

C.2 Other Parameters

Production Function: We need information on δ_s, δ_l, R, $\frac{K_l}{K_l+K_s}$, $\frac{K_l}{R}$, $\frac{wN}{R}$, and w at the industry-level to calibrate the industry-specific parameters ν, B, a, b, α and ε. We obtain these data from the US files of the EU KLEMS database, averaged over the years 2003–2005 at constant prices.

As we abstract from incentive distortions when calibrating the industry-specific parameters, we can combine the two FOCs of individual capital goods to get

$$\nu = \frac{1-\theta(1-\delta_l)}{1-\theta\left[1-\delta_s-\frac{K_l}{K_l+K_s}(\delta_l-\delta_s)\right]}\frac{K_l}{K_l+K_s}.$$

Notably, the steady-state share of long-term capital goods in the total capital stock is larger than ν, since the term $\frac{1-\theta(1-\delta_l)}{1-\theta\left[1-\delta_s-\frac{K_l}{K_l+K_s}(\delta_l-\delta_s)\right]}$ is strictly smaller than 1. This is due to the fact that user cost of capital are higher for short-term capital such that the share of long-term capital exceeds the Cobb-Douglas production exponent ν. Given ν, we can solve the first-order condition of the long-term capital good for a as

$$a = \frac{\frac{1}{\theta}-(1-\delta_l)}{\nu}\frac{K_l}{R}.$$

At the industry level, we approximate R by the average value added by firm in the sector. Likewise, b directly follows from optimal labor demand as

$$b = \frac{wN}{R},$$

where we analogously calculate N as average industry-level employment per firm. With a and b, we can directly recover ε and α as

$$\varepsilon = \frac{1}{1-a-b}, \quad \alpha = \frac{a}{a+b}.$$

Finally we can determine the demand-scaling parameter B, using labor demand as well as the production function, which then yields

$$B = \left(\frac{w^{\frac{b}{1-b}}R}{b^{\frac{b}{1-b}}\left(K_l^{\nu}K_s^{1-\nu}\right)^{\frac{a}{1-b}}}\right)^{\frac{1-b}{1-a-b}}.$$

Interest Rate: For the calibration of the industry-specific parameters, we abstract from incentive distortions and thus consider a long-run discount factor $\theta = \frac{1}{1+r}$. I.e., we neglect managerial share dilution when calibrating industry-level variables.[33] For r, we use the real interest rate for the United States from the year 2005, which was 2.981% according to World Bank (2020). While the

[33]We account for share dilution, however, when we compute the investment decision of firms in the exercise.

Table A.11: Transition Matrix β Before and After FAS 123R

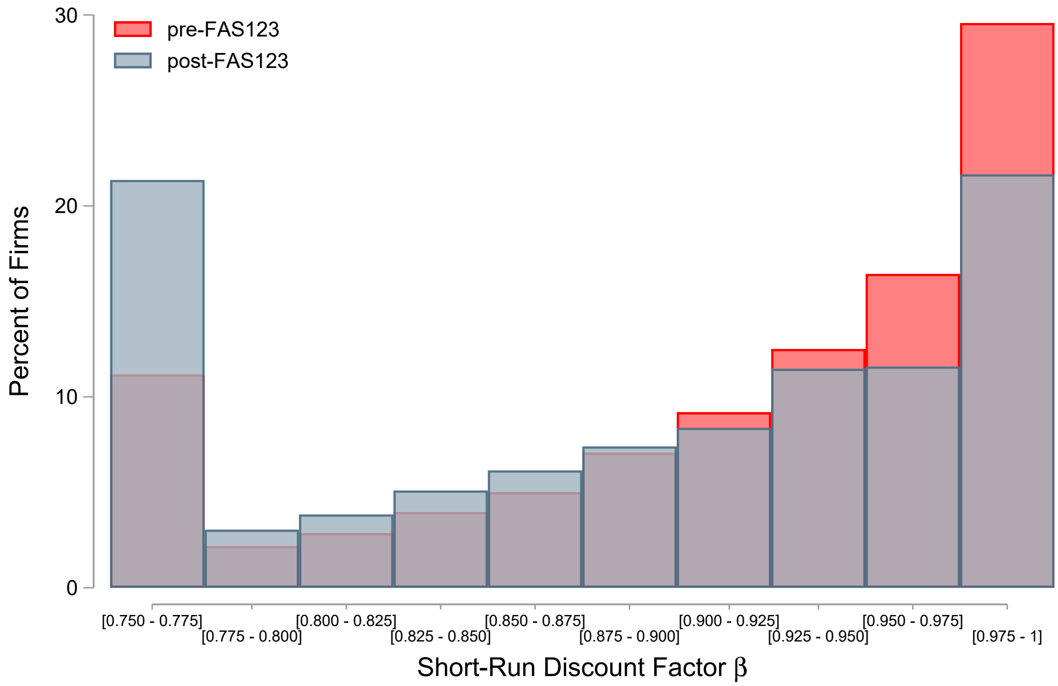
	β post-FAS-123 in 2007									
β pre-FAS-123 in 2005	I 0.75-0.775	II 0.775-0.8	III 0.8-0.825	IV 0.825-0.85	V 0.85-0.875	VI 0.875-0.9	VII 0.9-0.925	VIII 0.925-0.95	IX 0.95-0.975	X 0.975-1
I 0.75-0.775	**90.15**	1.01	1.55	0.97	1.35	1.21	0.53	0.58	0.19	2.46
II 0.775-0.8	13.46	**67.01**	1.92	2.56	1.92	2.88	2.56	1.92	0.96	4.81
III 0.8-0.825	10.59	1.81	**69.00**	3.10	3.36	2.07	2.07	3.62	1.55	2.84
IV 0.825-0.85	7.04	1.85	3.70	**66.67**	3.89	4.44	3.70	3.15	1.30	4.26
V 0.85-0.875	6.98	1.67	2.12	2.73	**67.69**	4.25	5.61	4.10	1.21	3.64
VI 0.875-0.9	5.29	1.53	2.82	2.23	4.35	**65.92**	6.11	5.64	2.35	3.76
VII 0.9-0.925	3.39	1.45	1.36	3.19	3.10	4.94	**63.6**	7.74	6.00	5.23
VIII 0.925-0.95	3.19	0.94	1.38	2.25	2.39	3.41	5.66	**66.06**	7.76	6.96
IX 0.95-0.975	1.80	0.50	0.87	1.49	1.61	3.10	4.34	9.06	**65.32**	11.91
X 0.975-0.1	2.29	0.45	0.58	0.81	1.16	1.81	1.42	3.42	6.93	**81.13**

Notes: The Table reports transition probabilities for FAS-123R-induced changes in β. We group betas into ten bins each ranging 2.25 percentage points. Data is left-censored at 0.75, which applies to 14.39% of the observations. Row i displays for a β grouped in bin i the probabilities of being in bins 1-10 after the reform. Therefore, rows sum up to 100%. Diagonal entries indicate the probabilities for β being unchanged after the reform.

definition of the proper discount factor is debatable, we justify our choice to take the real interest rate as we abstract from both, growth and risk.[34]

[34]The choice of r merits some discussion: in the US, around the time of the reform, the real interest rate fluctuated between a high of 6.845% in 2000 and a low of 1.137% in 2011. This happened against the background of an overall downward trend since the 1980s, which was overlaid between 2005 and 2007 by contractionary monetary policy. Over the years 2000–2009 the (geometric) average real interest rate in the US was about 3.677%, but for the years 2010–2019 it has fallen to 1.996%; between 2003 and 2008 the figure was 3.309%. It's thus not entirely clear which value one should choose as a steady-state value. However, our results would not change much if we used a different value for r. For private businesses, the discount factor should take into account risk premia (related to, inter alia, idiosyncratic uncertainty and the financing structure of the firm), and thus be smaller. On the other hand, due to technological progress and the growth of the overall economy, a firm should expect the demand shifter as well as its TFP to change over time, changing the size of the firm. I.e., if we reinterpret our model's steady state as a balanced growth path with growth rate g and with the variables of the model properly detrended, the firm's discount factor would effectively be $\theta = \frac{(1-\eta^e)(1+g)}{(1+r)}$, which effectively increases the discount factor.

Figure A.4: Changes in the Short-Run Discount Factor Around FAS 123R



Notes: The Figure depicts the empirical distribution of the parameter β before (red) and after (blue) the introduction of FAS 123R. We group βs into ten bins each ranging 2.25 percentage points. Data is left-censored at 0.75, which applies to 14.39% of the observations.

C.3 Sensitivity Analysis

C.3.1 Adjustment Costs

As we have noted before, the adjustment-cost parameter γ also affects the steady state because it alters the slope of the value function and consequently also the policy functions, whenever $\beta < 1$. To study the sensitivity of our results with respect to different values of γ, we either consider a value of γ that equals half its original value ($\underline{\gamma}$) or twice its original value ($\overline{\gamma}$).

Changing γ affects both, the resulting steady-state levels of capital goods and the dynamic response to a change in β. Concerning the steady state, the effect of a change in β is muted with $\overline{\gamma}$. Both capital goods fall by roughly one fifth less in response to a given reduction in β in steady state. Alternatively, capital goods fall by approximately one fifth more in steady state with $\underline{\gamma}$. This also changes the composition of steady-state capital stocks, although only relatively mildly. For example, consider a firm that experiences a reduction in its β from 1 to some lower value. If the firm faces low adjustment costs $\underline{\gamma}$ the fall in the share of long-term capital in total capital is roughly one fourth larger compared to the case with original adjustment costs. In contrast, if the firm faces high adjustment costs $\overline{\gamma}$, the share of long-term capital is less responsive and its fall is diminished by about one fourth. Considering the dynamic impact, we also see very intuitive results. When adjustment costs are higher, firms take longer to reach the new steady state and vice versa. To sum up, higher adjustment costs make capital stocks (and their composition) more rigid, in the sense that they become less responsive to changes in β.

C.3.2 Substitutability of Capital Goods

In the main analysis, we consider a Cobb-Douglas production function which implies that the elasticity of substitution between the capital goods equals one ($\sigma_k = 1$) such that both goods are independent from each other. Here, we consider the sensitivity of our results with respect to perturbations of σ_k. A first intuition is that the closer substitutes the two capital goods are ($\sigma_k \to \infty$), the stronger the differential impact of a change in β should be. On the contrary, the more the two types of capital are complements ($\sigma_k \to 0$), the weaker a differential impact one would expect. While this intuition is correct for most perturbations of σ_k, it comes with one caveat: with perfect substitutes, we are in a knife-edge case. For a range of β values, the firm then fully invests in only one type of capital. Consequently, there will be no within-firm reallocation for certain values of β in the limit $\sigma_k \to \infty$.

In our sensitivity analysis, we consider the range $\sigma_k \in [\underline{\sigma}_k = 0.5, \overline{\sigma}_k = 2]$ and find that our results did not qualitatively change as a drop in β still induces a decline in overall investment and a relative shift between the two capital goods. With $\underline{\sigma}_k$, this effect is weakened by roughly one half which is due to long-term capital falling less and short-term capital falling more than in the Cobb-Douglas case. With $\overline{\sigma}_k$, the effect is increased by about one half.

C.4 Numerical Solution Method

To illustrate the solution method, we continue with the notation introduced in the previous section. Since the labor decision in the problem above is simply determined by the first-order condition (B.3), we can write per-period operating profits as a function of $\mathbf{K}, \mathbf{K}'$ only by defining:

$$\pi^*(\mathbf{K}, \mathbf{K}', \xi) = \max_N \{\pi(\mathbf{K}, \mathbf{K}', N, \xi)\}. \quad \text{(B.31)}$$

Importantly, this function satisfies

$$\frac{\partial}{\partial K_j'} \pi^*(\mathbf{K}, \mathbf{K}', \xi) = \frac{\partial}{\partial K_j'} \pi(\mathbf{K}, \mathbf{K}', N, \xi), \quad j = l, s.$$

The optimization problem of the manager can be re-stated in recursive form as

$$\Gamma(\mathbf{K},\xi) = \max_{\mathbf{K}'} \{\pi^*(\mathbf{K},\mathbf{K}',\xi) + \beta\theta V(\mathbf{K}',\xi) \tag{B.32}$$

$$\text{s.t. } V(\mathbf{K}',\xi) = \pi^*(\mathbf{K}',\mathcal{K}(\mathbf{K}',\xi),\xi) + \theta V(\mathcal{K}(\mathbf{K}',\xi),\xi)\}. \tag{B.33}$$

Here, the future policy function $\mathcal{K}(\cdot)$ is defined as

$$\mathcal{K}(\mathbf{K},\xi) = \arg\max_{\mathbf{K}'} \{\pi^*(\mathbf{K},\mathbf{K}',\xi) + \beta\theta V(\mathbf{K}',\xi)\}. \tag{B.34}$$

Note that we assume that this policy function is time-invariant which results from our focus on symmetric strategies.

Next, to keep the notation concise, define the gradient of a function $f(\mathcal{K},\xi)$ in terms of elements of $\mathcal{K}$ to be given by

$$\nabla_{\mathbf{K}} f(\mathbf{K},\xi) = \left[\frac{\partial f(\mathbf{K},\xi)}{\partial K_l} \; \frac{\partial f(\mathbf{K},\xi)}{\partial K_s} \right]'.$$

We use similar notation for functions with multiple inputs, and the index of ∇ gives the input the gradient applies to. Then, the first-order conditions (B.5) can be stated as

$$\nabla_{\mathbf{K}'} \pi^*(\mathbf{K},\mathbf{K}',\xi) = -\beta\theta \nabla_{\mathbf{K}'} V(\mathbf{K}',\xi). \tag{B.35}$$

From (B.31), we can derive

$$\begin{aligned} \nabla_{\mathbf{K}'} \pi^*(\mathbf{K},\mathbf{K}',\xi) &= -\nabla_{\mathbf{K}'} C^K(\mathbf{K},\mathbf{K}') \\ &= -\begin{bmatrix} \gamma\left(\frac{K_l'}{K_l} - 1\right) + 1 \\ \gamma\left(\frac{K_s'}{K_s} - 1\right) + 1 \end{bmatrix}. \end{aligned}$$

That is, in terms of any capital good, we obtain a first-order condition

$$\gamma\left(\frac{K_j'}{K_j} - 1\right) + 1 = \beta\theta \frac{\partial V}{\partial K_j'}(\mathbf{K}',\xi).$$

Note that this can be readily solved for K_j:

$$K_j = \frac{K_j'}{1 + \frac{\frac{\partial V}{\partial K_j'}(\mathbf{K}',\xi) - 1}{\gamma}}. \tag{B.36}$$

Equation (B.36) is the central ingredient in the endogenous grid method we apply. This method is described by algorithm 1 below.

Essentially, we start with a set of G gridpoints $\tilde{\mathcal{K}}' = (\tilde{\mathbf{K}}_h')_{h=1,\dots,G}$, which represent different outcomes of $\mathbf{K}'$, and an initial (differentiable) guess $\hat{V}_0(\cdot)$ for $V(\cdot)$. By differentiating $V(\cdot)$, we get the gradient at each point in $\tilde{\mathcal{K}}'$. Then applying the backward induction step in (B.36), we can solve for the optimal solution of the previous manager. Next, we update our guess for the continuation value function $V(\cdot)$ according to the profit function and our current guess. We then iterate on this until convergence is achieved.

This algorithm is implemented as MATLAB code (tested against MATLAB R2018b and R2020a) and can be found in the replication package.

The sample of 1,000 firms is based on idiosyncratic parameter draws 30-by-30 in the (K_l', K_s')-space. The coordinates of the gridpoints correspond to Chebyshev nodes in a range around the steady state with $\beta = 1$. To be precise, the grid ranges from 0.3 to 1.2 of the analytical steady state of that parameterization. As an interpolation scheme $\rho(\cdot)$ we opt for Chebyshev polynomials up to degree 10 in either dimension.[35] Since the endogenous grid method inherently involves interpolation with a changing set of interpolation bases, the domain of the chosen functions was expanded as needed to keep all points within the domain.

To specify an initial guess for the value function, we follow the following procedure: initially, we consider a case where $\beta = 1$, for which a steady state can be derived analytically. As an initial guess of the value function, we simply assume that the model would converge uniformly to that steady state within a certain period. Using the resulting net present value of profits gives a reasonably accurate initial guess for the case of $\beta = 1$. However, for lower $\beta < 1$, this does not necessarily lead to convergence. For this reason, we first solved the model for the $\beta = 1$ case. Then, we use the final value function computed and use this as an initial guess to solve the model with a slightly lower value of β. Repeating this process while slowly decreasing β yields satisfactory convergence. The entire process is then repeated for all 1,000 parameterized firms in the sample.

[35] We have chosen Chebyshev polynomials because they have preferable interpolation properties compared to other polynomials functions. Also, Splines were considered, but computing the gradient of a spline is a computationally expensive exercise and experiments with cubic splines showed inferior convergence properties. We also experimented with Chebyshev polynomials with a total degree of 30. However, most coefficients with a higher degree are virtually identical to zero. In fact, higher order polynomials present a problem for the algorithm since for these higher order polynomials, the gradient quickly becomes very large in absolute terms, even if the corresponding coefficient is small; this generates additional sources of numeric error, which leads to far worse convergence properties. Given that this method ultimately generates an inverse of the policy function, we eventually have to back the real policy functions out. This final step is done using cubic splines.

Algorithm 1: Version of EGM used in the model solution

Set i_{max} as well as convergence thresholds $\bar{\epsilon}^v, \bar{\epsilon}^{invp} > 0$ for the continuation value and inverse policy, respectively. Pick a parameter vector ξ, a set of gridpoints $\tilde{\mathcal{K}}' = (\tilde{\mathbf{k}}'_g)_{g=1,\ldots,G}$, an initial guess for each of these points, i.e. $\hat{V}_{0,g}$ for $g = 1, \ldots, G$, and an interpolation scheme $\rho(x, X, Y)$ to be used. Find interpolated values $v_0(\mathbf{K}) = \rho(\mathbf{K}, (\mathbf{k}'_g)_{g=1,\ldots,G}, (\hat{V}_{0,g})_{g=1,\ldots,G})$.

Set *continue*=true. set i=1.

while *continue* **do**

  for g=1,…,G **do**

    Set $\hat{\mathbf{k}}_{j,i,g} = \frac{\gamma k'_{jg}}{\gamma + \beta\theta \frac{\partial}{\partial \mathbf{K}'_j} v_{i-1}(\mathbf{k}'_g) - 1}$ for $j = l, s$.

    Set $\tilde{v}_g = \Pi(\mathbf{k}_{i,g}, \mathbf{k}_g, \xi) + \theta \hat{V}_{i-1,g}$.

  Find interpolant $v_i(\mathbf{K}) = \rho(\mathbf{K}, (\mathbf{k}_{i,g})_{g=1,\ldots,G}, (\tilde{v}_g)_{g=1,\ldots,G})$.

  for g=1,…,G **do**

    Set $\hat{V}_{i,g} = v_i(\mathbf{K}_g)$.

    Set $\epsilon^v_{ig} = \left| \frac{\hat{V}_{i,g}}{\hat{V}_{i-1,g}} - 1 \right|$.

    Set $\epsilon^{invp}_{jig} = \left| \frac{k_{j,i,g}}{k_{j,i-1,g}} - 1 \right|$.

  if $\max_{g\in(1,\ldots,G)}\{\epsilon^v_{ig}\} < \bar{\epsilon}^v$ *and* $\max_{j\in(l,s),g\in(1,\ldots,G)}\{\epsilon^{invp}_{ig}\} < \bar{\epsilon}^{invp}$ **then**

    Set *continue*=false.

  else

    Set i=i+1;

Obtain policy function as $\mathcal{K}(\mathbf{K}, \xi) \approx \tilde{\mathcal{K}}(\mathbf{K}, \xi) := \rho(\mathbf{K}, (k_{i,g})_{g\in\{1,\ldots,G\}}, (\mathbf{k}_g)_{g\in\{1,\ldots,G\}})$

Modification in the Pseudo-General-Equilibrium Exercise: If we want to use the previous algorithm in a general-equilibrium environment, we need to take into account that each firm now also takes aggregate state variables into account. These include in our framework the two aggregate capital stocks, or more precisely their distribution across all active firms. In the related literature with heterogeneous agents or firms (e.g., Krusell and Smith 1998, Khan and Thomas 2013), the distribution of capital across agents or firms becomes an important state variable, which is an infinitely-dimensional object with infinitely many firms or agents and thus needs to be approximated. In our simulated sample, we only use a finite number of firms (1,000) but accounting for this we would still have a 2,000-dimensional state variable for capital goods alone (1,000 firms $\times$ 2 capital goods). Since we are not interested in the dynamics per se, we can simplify matters a lot by only focusing on aggregate steady states.

When the economy at large is in a steady state, we can use our algorithm from before to solve for each single firm. Note that the only aggregate variable relevant for the firm's problem is the industry-level demand shifter B. It is straightforward to show that this shifter proportionally scales the scale of the firm. To make this more precise, the policy function now depends on the demand shifter as well as on parameters ξ:

$$\mathbf{K}' = \mathcal{K}\left(\mathbf{K}, B, \xi\right). \tag{B.37}$$

Notably, it can be shown that the policy functions scale with the demand shifter as follows:

$$\mathcal{K}(\mathbf{K}, B, \xi) = B \cdot \mathcal{K}\left(\frac{1}{B}\mathbf{K}, 1, \xi\right). \tag{B.38}$$

From this, we can directly infer that the steady-state capital stock of the firm directly scales with B.

The firm affects the general equilibrium through its factor choices, its output Q_f and its price level P_f. Notably, while a firm's steady-state output Q_f is directly proportional to B its price in steady state is fully determined by technology and the relative composition of its factor choices. We have just argued that the entire policy function is scaled up or down by B and as a a result, B does not affect the relative composition of its factor inputs in steady state. I.e., the steady-state price level of the firm is independent of macroeconomic outcomes. This allows us to solve for the pseudo-general-equilibrium solution in a simple way. For each firm, we can simply solve the firm's problem for an arbitrary B and obtain the firm-level steady state. From now on, we only refer to steady-state values of all variables. We can do this exercise for our entire sample of firms, $f = 1, \ldots, 1,000$. As a result, we have a steady-state price level P_f for each firm. The resulting steady-state price level can be used to infer sectoral and aggregate price levels $\mathcal{P}_s, \mathcal{P}$ using (B.10) and (B.7). From (B.8), it is possible to show that the demand shifter in any sector is then proportional to aggregate demand $\mathcal{Q}$ times a function purely dependent on the pricing choices of all firms. As a result, also the quantity produced by any firm, and ultimately factor choices are simply proportional to aggregate demand.

Thus, to derive general equilibrium, we simply obtain all the relevant price levels.

Using (B.8) and (B.11), we can obtain

$$Q_f = \psi_s P_f^{-\varepsilon_s} \mathcal{P}_s^{\varepsilon_s - 1} \mathcal{P} \mathcal{Q}, \tag{B.39}$$

i.e., the output of any firm and hence its factor demand is proportional to aggregate demand.

Here, since prices are fully determined by parameters and firms' incentive structure, we get

$$Q_f = p_f \mathcal{Q}, \tag{B.40}$$

where $p_f = \psi_s P_f^{-\varepsilon_s} \mathcal{P}_s^{\varepsilon_s - 1} \mathcal{P}$ does not depend on $\mathcal{Q}$. From the firm's individual problem, we can derive a steady-state ratio of total labor used to output produced as $n_f = \frac{\bar{N}_f}{Q_f}$, which again is independent of $\mathcal{Q}$. Total labor demand is then given by

$$\bar{N} = \sum_{f=1} \bar{N}_f = \sum_{f=1}^{\mathcal{N}_f} (n_f p_f) \mathcal{Q}.$$

$\mathcal{Q}$ directly follows by imposing market clearing on the labor market. We then scale each firm accordingly, taking into account p_f and n_f.