Succession*

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Abstract

We develop a dynamic model of CEO succession. In the model, the board learns about the CEO's and successor's ability and can replace the CEO with the successor or an external candidate. Our model explains the prevalence of internal CEO successions, the apparent absence of succession planning, and the delays until appointing a new CEO. We also show that as the labor market for executives becomes more efficient the fraction of successors directly hired from the labor market decreases. Finally, in our model succession planning can foster managerial entrenchment but can also result in the CEO getting replaced more easily.

Keywords: succession, CEO labor markets, CEO turnover, managerial entrenchment.
JEL Classifications: G30, G34, M12.

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CEOs have been shown to leave a long-lasting impact on firms they run (Bertrand and Schoar, 2003; Bandiera et al., 2020; Bennedsen et al., 2020; Jenter et al., 2021). Therefore, CEO hiring decisions and succession planning should be of the utmost importance for firms. However, in practice many firms have poor succession planning (Fernández-Aráoz et al., 2021). In this paper, we develop a dynamic model of CEO succession, which allows us to study how firms hire and fire CEOs and how they set up their succession plans.

Our model provides several novel findings. First, we rationalize the empirical prevalence of internal successions documented by Parrino (1997), Huson et al. (2004), and Cziraki and Jenter (2022).[1] Second, our model explains the apparent absence of succession planning within firms (Cvijanović et al., 2022; Larcker et al., 2022) and the extensive delays when appointing new CEOs (Rivolta, 2018; Gabarro et al., 2022).[2] Third, we show that more efficient labor markets are associated with a higher incidence of internal successions, indicating that internal successions may not necessarily be a sign of inefficiencies. Finally, we demonstrate that succession planning can foster managerial entrenchment but in certain cases it can also result in the CEO getting fired more easily.

In the model, the firm employs a CEO and a successor, which could for example be the COO or the president.[3] Over time, the board learns about the CEO's and the successor's ability from their work within the firm. The CEO's ability directly affects the firm's cash flows. At any point in time, the board can decide to replace the CEO, but doing so is costly.[4] When appointing the new CEO, the board can either promote the successor—an

[1] Cziraki and Jenter (2022) document that 80% of new CEOs are insiders and the board is familiar with more than 90% of new CEOs.

[2] Cvijanović et al. (2022) report that even though the prevalence of succession plan disclosure reached 36% in 2010, on average only 16.4% of firms have ever disclosed their succession plans. Rivolta (2018) finds that after an unplanned CEO departure firms experience on average 112 days of delay in succession.

[3] Larcker and Tayan (2022) report that prior to becoming the CEO, the executive was 33% of the time a president/divisional, 27% of the time a COO, and 9% of the time a CFO.

[4] These could take the form of direct costs such as deferred compensation or golden parachutes or indirect costs, for example pressure on the stock price or personnel turnover. Clayton et al. (2005) document that stock price volatility increases substantially following CEO turnover. Taylor (2010) and Nickerson (2013) provide evidence that the cost of replacing a CEO is significant and amounts to roughly 1.33% and 2.18%

internal succession—or engage in a costly search in the labor market to find an external candidate—an *external succession*. In general, promoting the successor is less risky as the board has more information about the successor's ability while it does not learn about the external candidate's ability.

When deciding on the new CEO appointment, the board compares the successor's expected ability to the expected ability of the external candidates. Consequently, if the board receives positive information about a successor, then the successor is more likely to become the new CEO. In contrast, when receiving negative information about the successor, the board is more inclined to hire an external candidate. Thus, learning about the successor's ability drives internal successions and helps explain the empirically observed willingness of firms to hire their CEOs from the inside (e.g., Cziraki and Jenter, 2022).

We use the model to study how labor market efficiency influences succession planning. In particular, we show that a more efficient labor market for executives results in more internal successions. Less severe labor market frictions affect the firm in two ways. First, hiring external candidates becomes less costly, which increases the incidence of external successions. Second, replacing the successor is also less costly, which results in firms employing successors of higher expected ability and therefore an increase in internal successions. We show that the second effect dominates as the labor market becomes more efficient so that the board prefers to promote internally. This result continues to hold in a labor market equilibrium in which the ability of external candidates is endogenous. One important implication of this result is that higher levels of internal successions may not be indicative of inefficiencies in the labor market for CEOs, as implied by other theories based on agency conflicts or behavioral biases (e.g., Hermalin and Weisbach, 1998).

Additionally, our results demonstrate that the apparent absence of succession planning (Cvijanović et al., 2022; Larcker et al., 2022) and the long delays in appointing new CEOs can sometimes be optimal for firms (Rivolta, 2018; Gabarro et al., 2022). This happens for

of firms' assets.

two reasons. First, because it is expensive for firms to appoint, fire or replace their CEOs. Second, because appointing a subpar CEO today is costly as it increases the effective cost of hiring a new CEO in the future. The reason is that the firm has to forgo future cash flows generated by this subpar CEO when letting her go. As a consequence, boards might endogenously delay appointing a new CEO until a suitable candidate is found, rather than hiring a subpar candidate today.

We also use our model to study how entrenchment influences succession planning. To this end, we extend the model by allowing the CEO to sabotage the successor, which results in the CEO becoming entrenched. This sabotaging could, for example, come in the form of the CEO undermining the successor by refusing to endorse or collaborate with her or by spreading rumors.[5] In practice, CEOs play a crucial role in the succession process (Bower, 2012; Berns and Klarner, 2017) and have been shown to sabotage successors (Boeker, 1992; Cannella and Shen, 2001; Zhang, 2006). In our model, by sabotaging the successor, the CEO is less likely to get replaced by the successor. We thus model a novel channel through which the CEO can become entrenched. We show that compensation plays a crucial role in determining the CEO's incentives to sabotage the successor. In particular, equity-based compensation lowers the CEO's incentives to sabotage the successor, because doing so negatively impacts the firm's equity value. On the other hand, fixed or profit-based compensation increases the CEO's incentives to sabotage the successor if it prolongs the CEO's tenure and therefore the value of compensation. As a consequence, more equity-based compensation decreases managerial entrenchment.

The board responds to the CEO sabotaging the successor in two ways. First, the board responds by changing its hiring policy. That is, the board optimally delays replacing a successor. The reason is that the CEO will also sabotage future successors, which lowers the board's incentives to hire any successor. This change in hiring policy negatively impacts

[5]For example, it has been reported that Disney's CEO Bob Iger has undermined his hand-picked successor Bob Chapek. See Bob's Your Uncle at Disney in the Wall Street Journal of December 26, 2022.

the successor's expected ability above and beyond the direct effect of the CEO's sabotage, which results in the CEO becoming even more entrenched. Second, the board responds by changing its promotion policy. In particular, the board replaces the CEO with the successor more rapidly. This happens because knowing that the CEO sabotages the successor lowers the option value of delaying succession. In response, the board changes its promotion policy and replaces the CEO with the internal successor earlier. Trying to become entrenched can therefore backfire for the CEO since the board anticipates the CEO's actions and responds optimally. We thus show that the CEO sabotaging the successor leads to managerial entrenchment and that the board's response can alleviate (via promotions) or exacerbate (via hiring) the managerial entrenchment. By doing so, we present a novel channel through which entrenchment can influence corporate policies.

Our paper contributes to several strands of the literature. First, we add to the theoretical literature on the market for CEOs (e.g., Murphy and Zabojnik, 2004; Hermalin, 2005; Tsoulouhas et al., 2007; Gabaix and Landier, 2008; Terviö, 2008; Eisfeldt and Kuhnen, 2013; Nickerson, 2013; Huang, 2016; Anderson et al., 2018; Celentano and Mello, 2023). Most closely related are Hermalin (2005) and Celentano and Mello (2023). In Hermalin (2005), the board chooses whether to appoint an external or internal CEO with uncertain ability after which it can decide to learn about the CEO's ability and possibly replace her with a new CEO. However, there is no notion of succession planning, which is of key interest in our paper. Celentano and Mello (2023) use a structural approach to estimate the cost and benefits of succession planning. In contrast to this paper, we allow the board to select a successor and let the firm learn about the successor thereby microfounding the succession planning. One of our novel predictions is that less severe frictions in the labor market makes external successions less likely because lower frictions alter firms' hiring dynamics, which increases the likelihood of firms already employing a high-expected-ability successor. As a consequence, high levels of internal succession (e.g., Parrino, 1997; Cziraki and Jenter, 2022) may not necessarily be a sign of inefficiencies in the market for CEOs.[6,7]

Second, our paper contributes to the literature on managerial entrenchment. Existing models show that managerial entrenchment can be driven by investment, financing, boards of directors, compensation, or reputational concerns (e.g., Shleifer and Vishny, 1989; Zwiebel, 1996; Hermalin and Weisbach, 1998; Almazan and Suarez, 2003; Kuhnen and Zwiebel, 2008; Casamatta and Guembel, 2010). However, in our setup the CEO becomes more entrenched by sabotaging the successor. Most closely related to our work is Shleifer and Vishny (1989), who show that CEOs want to undertake actions that make them more valuable to the firm relative to possible successors, which leads to managerial entrenchment. Our model can be considered the flip side of Shleifer and Vishny (1989), in that in our setting the manager undertakes actions which make it harder for the successor to run the firm and increase the opportunity cost of hiring the successor.[8] We also show that the board optimally responds to the CEO's sabotage by delaying hiring a new successor, which fosters managerial entrenchment and speeds up promoting the successor, causing the CEO to get fired more easily.

Section I presents the baseline model. Section II analyses this baseline model and derives the main results. Section III extends the model to allow for sabotage, which leads to managerial entrenchment. Section IV concludes. All proofs are in Appendix A, and Appendix B describes the numerical algorithm used to solve the model.

[6]There also exists a related theoretical literature in labor economics that analyzes external hires versus internal promotions (e.g., Chan, 1996; Chen, 2005; Waldman, 2003; DeVaro and Morita, 2013). In contrast to this literature, we study the dynamics of external hires versus internal promotions and how the existing CEO can sabotage internal promotions thereby becoming more entrenched. See Lazear and Oyer (2007), Waldman (2013), or Oyer and Schaefer (2011) for surveys of the personnel economics literature.

[7]See Berns and Klarner (2017) for a review of the CEO succession literature in management. They mention that in practice CEO succession is a continuous process in which the incumbent CEO plays an important role, as in our model.

[8]There also exists a related theoretical literature in economics that studies sabotage (e.g., Salop and Scheffman, 1983; Lazear, 1989; Chen, 2003, 2005). Unlike this literature, we study the CEO's incentives to sabotage their subordinates (the successor) and the corresponding response by the firm. See Chowdhury and Gürtler (2015) for a survey of the literature on sabotage in contests.

I Model

In this section, we develop a dynamic model of CEO succession. Time t is continuous. There exists an infinitely-lived firm owned by risk-neutral shareholders who discount cash flows at rate $r > 0$. The firm is run by a board so as to maximize shareholders' equity value. The firm can employ a CEO and a successor. The board can decide to replace the CEO by the successor or byan external candidate. This process repeats itself over time, which allows us to study the succession of current and future CEOs within the firm.

A CEO

At time zero, the firm employs a CEO of ability θ^c, which can be either low or high $\theta^c \in \{L, H\}$ where $L = 0$ and $H = 1$. This ability can also be interpreted as the CEO's fit with the firm. The CEO's ability is unknown to the board, which has a prior $c \in [0, 1]$ about it being high.[9] The firm generates cash flows dX_t, which depend on the CEO's ability θ^c.

$$dX_t = (\mu + \theta^c)\, dt + \frac{1}{\phi^c} d\tilde{B}_t^c,$$

where $\mu \geq 0$ measures the cash flows unrelated to the CEO's ability, $\tilde{B}_t^c$ is a standard Brownian motion, and $\phi^c \geq 0$ is the "speed" of learning about the CEO's ability. Higher speed of learning ϕ^c implies that cash flows dX_t are less noisy and therefore more informative about the CEO's ability. A higher μ implies that the CEO is less important for the firm's cash flows.

Given the cash flows dX_t, the board updates its beliefs about the CEO's ability. Let $C_t = \mathbb{E}_t [\theta^c]$ be the CEO's expected ability given the information the board has acquired up to time t.[10] The CEO's expected ability C_t can also be interpreted as the probability that

[9] In the baseline model, only the board undertakes actions and therefore it does not matter what the CEO and successor know.

[10] The operator $\mathbb{E}_t[\cdot]$ denotes an expectation given the board's beliefs conditional on the information avail-

the CEO's ability is high, as $L = 0$ and $H = 1$. As in Daley et al. (2023), Bayes' rule implies that the dynamics of the CEO's expected ability are

$$dC_t = \phi^c C_t(1 - C_t)\phi^c(dX_t - (\mu + C_t)\, dt) = \phi^c C_t(1 - C_t)dB^c_t,$$

where B^c_t is a standard Brownian motion given the information available to the board. From this equation it becomes clear that a higher speed of learning ϕ^c—less noisy cash flows—lead to a faster updating of beliefs. Furthermore, when beliefs are close to zero or one, they move at a slower pace as Bayes' rule implies that more information is required to move beliefs.

Given the boards beliefs, the CEO's expected ability C_t thus directly impacts the firm's perceived performance (Bertrand and Schoar, 2003; Bandiera et al., 2020) as the cash flows are

$$dX_t = (\mu + C_t)\, dt + \frac{1}{\phi^c} dB^c_t.$$

If the firm does not employ a CEO at time zero, then it generates cash flows μdt, which is in expectation equivalent to $c = 0$.[11,12]

B Successor

The firm can also employ a successor. The successor could, for example, be the firm's current COO or CFO (Larcker and Tayan, 2022). The successor is of ability θ^s, which can be either low or high $\theta^s \in \{0, 1\}$. The successor's ability is unknown to the board, which has a prior $s \in [0, 1]$ about it being high. Over time, the board receives news Y_t about the successor's ability by observing the successor's work (Harris and Holmstrom, 1982). The dynamics of

able up and until time t.

[11]Shareholders are risk-neutral and therefore they are indifferent between receiving zero μdt or dX_t conditional on $C_t = 0$, which yields expected cash flows of $\mathbb{E}_t [dX_t|C_t = 0] = \mu dt$.

[12]This can also be interpreted as the firm employing an interim CEO with low ability at no cost.

the news are

$$dY_t = \theta^s + \frac{1}{\phi^s} d\tilde{B}_t^s,$$

where $\tilde{B}_t^s$ is a standard Brownian motion, which is independent of $\tilde{B}_t^c$, and $\phi^s \geq 0$ is the "speed" of learning about the successor's ability.As before, this setup implies that the dynamics of the successor's expected ability given the information the board has acquired up to time t, $S_t = \mathbb{E}_t[\theta^s]$, are

$$dS_t = \phi^s S_t(1 - S_t)\phi^s(dY_t - S_t dt) = \phi^s S_t(1 - S_t) dB_t^s,$$

where B_t^s is a standard Brownian motion, which is independent of B_t^c, given the information available to the board. If the firm does not employ a successor at time zero, then $s = 0$. From now on, all dynamics of the state variables (c, s) and expectations are under the board's beliefs.

C Succession

CEOs can depart for exogenous reasons (e.g., related to death as in (Nguyen and Nielsen, 2014) or (Bennedsen et al., 2020)) and endogenous reasons (e.g., due to bad performance as in Jenter and Lewellen, 2021). Thus, we assume that the CEO's contract can be terminated either exogenously, which happens with intensity $\lambda \geq 0$, or endogenously, when the board decides to replace the CEO.[13]

If the board decides to replace the CEO with the successor then it incurs a replacement cost $K > 0$ as in Taylor (2010).[14] Let τ_R be the time at which the board replaces the CEO

[13] We could incorporate poaching of the successor by competitors in a similar way. The successor would leave with a Poisson intensity that could also depend on the CEO and successor's ability.

[14] These could take the form of direct costs such as deferred compensation or golden parachutes or indirect costs, for example pressure on the stock price (Clayton et al., 2005) or personnel turnover. Taylor (2010) provides estimates suggesting that the board of directors acts as if the costs associated with CEO replacement

with a successor of expected ability $S_{\tau_R^-}$.[15] As soon as this happens, cash flows dX_t starts depending on the successor's ability, which is high with probability $S_{\tau_R^-}$. The board thus performs due diligence on the successor, which can be seen as a *real option* (Daley et al., 2023).

The board can also search for external candidates on the executive labor market to replace either the CEO or the successor. However, engaging in the search process is costly as it requires incurring a fixed cost $\Phi \geq 0$. In practice, the search costs come in the form of hiring an executive search firm (Khurana, 2000) or offering sign-on bonuses (Xu and Yang, 2016).[16] The next time the board searches for an external candidate is at the time τ_E. When engaging in an external search, the board meets an external candidate. The external candidate can have a low or a high ability $\theta^e \in \{0, 1\}$, which is unknown to the board. All external candidates have expected ability $e \in [0, 1]$, which is also the probability that the candidate's ability is high. In sum, when engaging in an external search, the board incurs the search cost Φ and then meets an external candidate with expected ability e. The board has two options. First, it can decide to replace the CEO with the external candidate at a cost K. In this case, the firm's cash flows start depending on the external candidate's ability. Second, the board can replace the current successor with an external candidate at no additional cost. In this case, the news about the successor start depending on the external candidate's ability. Consistent with our model, Fee and Hadlock (2004) find that "firms continually update their assessments of their non-CEO senior executive personnel and regularly remove suboptimal managers". Given that the expected ability of the external candidate e is known, the board has no incentive to incur the search cost and not hire the external candidate. The firm can replace its CEO and successor multiple times, and therefore we are dealing with an infinitely

amounted to as much as \$200 million for the average Compustat firm. See also Nickerson (2013).

[15] Where $t^- = \lim_{s \uparrow t} s$ indicates the left limit of t.

[16] For example, in 2018, it was announced that Andrea Orcel would leave UBS and become the new CEO of Santander. Santander agreed to pay Orcel a sign-on bonus of up to €52 million to compensate him for forgone remuneration. See Santander offered a €52*m* sign-on to Andrea Orcel in the Financial Times of July 15, 2019.

repeated real option problem (e.g., Fischer et al., 1989; Mauer and Ott, 1995; Hugonnier et al., 2015).[17]

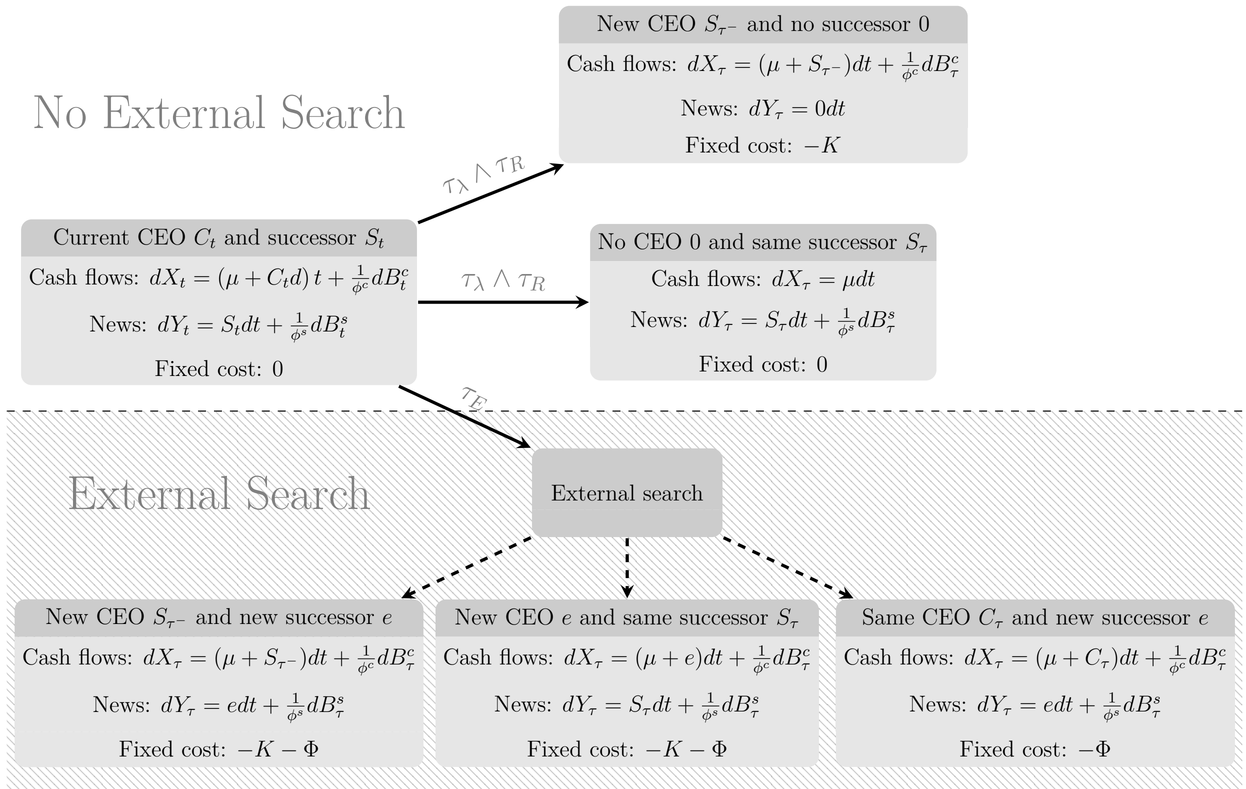

Figure 1: **Management Reshuffles.** The figure describes all possible transition dynamics within the management, including the new cash flows and news that the firm generates given the board's beliefs and possible fixed costs of hiring and search it incurs. $\tau_\lambda \wedge \tau_R = \min\{\tau_\lambda, \tau_R\}$ and $\tau = \min\{\tau_\lambda, \tau_R, \tau_E\}$.

Figure 1 plots possible management reshuffles in the model. Given a CEO with expected ability C_t and a successor with expected ability S_t the firm generates cash flows $dX_t = (\mu + C_t)\, dt + \frac{1}{\phi^c} dB^c_t$ and news $dY_t = S_t dt + \frac{1}{\phi^s} dB^s_t$. If the CEO leaves for exogenous τ_λ or endogenous τ_R reasons, then the board has two options. First, it can promote the successor

[17] We can extend the model to also encompass an internal labor market in which the board can search for a candidate to become the new CEO or successor. These candidates would have an expected ability e^{int} and come at a cost Φ^{int}. To keep the model parsimonious, we focus on the case with only an external labor market.

to become the CEO which requires a fixed cost K, in which case the firm's cash flows become $dX_\tau = (\mu + S_{\tau^-})dt + \frac{1}{\phi^c}dB^c_\tau$ where $\tau = \min\{\tau_\lambda, \tau_R, \tau_E\}$ and there is no news $dY_\tau = 0dt$. Second, the board can decide not to appoint any CEO and the firm generates no cash flows in this case the news remains $dY_\tau = S_\tau dt + \frac{1}{\phi^s}dB^s_\tau$. At any time, the board can also decide to search for an external candidate τ_E, which requires incurring the search cost Φ. There are three scenarios associated with the external search. First, the external candidate can replace the current CEO, which results in cash flows becoming $dX_\tau = (\mu + e)dt + \frac{1}{\phi^c}dB^c_\tau$, the news remaining $dY_\tau = S_\tau dt + \frac{1}{\phi^s}dB^s_\tau$, and the firm incurring the replacement cost K. Second, the external candidate can replace the successor and the successor becomes the CEO. In this case, cash flows become $dX_\tau = S_{\tau^-}dt + \frac{1}{\phi^c}dB^c_\tau$, the news becomes $dY_\tau = edt + \frac{1}{\phi^s}dB^s_\tau$, and the firm also incurs the replacement cost K. Finally, the external candidate can replace the successor. If this happens, the cash flows remain at $dX_\tau = C_\tau dt + \frac{1}{\phi^c}dB^c_\tau$ but the successor now has expected ability e instead of S_{τ^-} and therefore the news becomes $dY_\tau = edt + \frac{1}{\phi^s}dB^s_\tau$. The board can also replace both the CEO and successor with external candidates. This would be equivalent to performing an external search twice, as in Figure 1, with one search resulting in replacing the CEO and the other search in replacing the successor.

D Equity Value

Our setup implies that the equity value $V(c,s)$ depends on both the expected ability of the CEO c and that of the successor s. If at time zero the firm employs no CEO, then $c = 0$ and if at time zero the firm employs no successor, then $s = 0$. Let $\tau = \min\{\tau_\lambda, \tau_R, \tau_E\}$, then the equity value is

$$V(c,s) = \sup_{\tau_R,\tau_E}\Bigg\{\mathbb{E}_{c,s}\left[\int_0^\tau e^{-rt}dX_t + \mathbb{I}_{\{\tau<\tau_E\}}e^{-r\tau}\max\{V(S_{\tau^-},0) - K, V(0,S_\tau)\}\right] \\ + \mathbb{E}_{c,s}\left[\mathbb{I}_{\{\tau=\tau_E\}}e^{-r\tau}\left(\max\{V(e,S_\tau) - K, V(S_{\tau^-},e) - K, V(c,e)\} - \Phi\right)\right]\Bigg\}, \quad (1)$$

where the operator $\mathbb{E}_{c,s}[\cdot]$ denotes an expectation given the board's beliefs conditional on a CEO with initial expected ability c and a successor with initial expected ability s. The first term corresponds to cash flows generated by the current CEO, dX_t, until the CEO leaves (exogenously or endogenously). The second term reflects what happens when the CEO leaves and the firm has no external candidate $\tau < \tau_E$. In this case, the board either replaces the CEO by the successor $V(S_{\tau^-}, 0) - K$ or appoints no new CEO and keeps on employing the successor $V(0, S_\tau)$. The third term captures the effect of searching for an external candidate $\tau = \tau_E$. In that case, the external candidate can either *i)* replace the CEO $V(e, S_\tau) - K$, *ii)* replace the successor and the successor becomes the CEO $V(S_{\tau^-}, e) - K$, or *iii)* replace the successor $V(c, e)$. These three different possibilities are also summarized in the external search part of Figure 1.

From the equity value and the cash flows dX_t it follows that the firm always generates a cash flow μdt, which is independent of the ability of the CEO. As a consequence,

Corollary 1 (Non-CEO Cash Flows μdt and Optimal Policies)**.** *The firm value $V(c, s)$ satisfies*

$$V(c, s) = V(c, s|\mu = 0) + \frac{\mu}{r}$$

and therefore the board's optimal policies do not depend on the cash flows unrelated to the CEO's ability μ.

E Optimal Policies and Ability Dynamics

Figure 2 describes the different actions the board takes in various regions of the state space (c, s). There are five different regions. *i)* In the white region, the board does not undertake any action and the current CEO and successor continue running the firm. The CEO and successor are of sufficient expected ability so that the board has no incentive to replace either of them. *ii*) In the blue region, the successor gets promoted to CEO and a new successor gets appointed. The successor is significantly better than the CEO and therefore the board decides to replace the CEO with its successor. The board then fills the vacant successor position by an external candidate. *iii*) In the light red region, a new external CEO gets appointed. The outside candidates dominate the CEO and the successor. Therefore, the CEO gets replaced by an external candidate. *iv*) In the dark red region, a new external CEO and successor get appointed. Both the current CEO and the successor are of insufficient expected ability and get replaced by external candidates. *v*) In the gray region, a new successor gets appointed. The successor is sufficiently worse than the external candidates and therefore is replaced by the board.

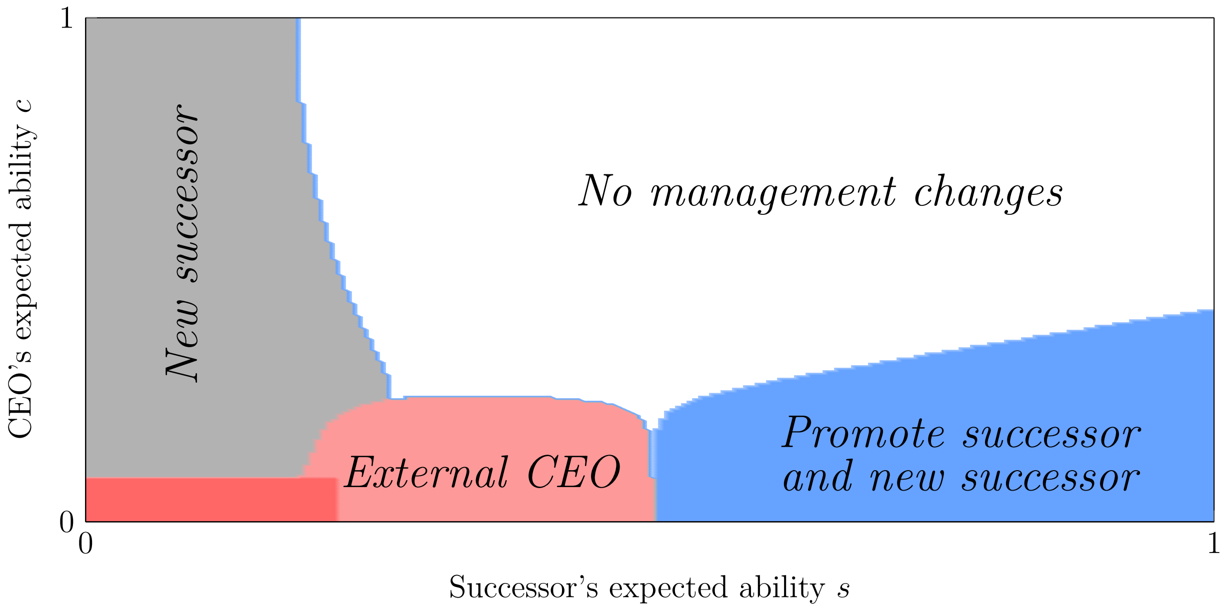

Figure 2: **Optimal Succession Policy**. The figure shows the solution of the model given the parameters $(r, \lambda, \phi^c, \phi^s, K, e, \Phi) = (4\%, 10\%, 0.5, 0.5, 0.4, 0.5, 0.5)$. Appendix B describes the numerical algorithm used to solve the model.

We provide more intuition regarding the dynamics of CEO and successor expected ability (c, s) within the model in Figure 3, which shows three possible sample paths.

1. (c_1, s_1): The firm starts at (c_1, s_1). The board receives negative news about the successor and positive news about the CEO, which results in a move to (c_1', s_1'). At this point, it is optimal for the board to replace the successor since the likelihood of the successor becoming a suitable CEO is too low. As a consequence, (c, s) jumps to (c_1', e).

2. (c_2, s_2): The firm starts at (c_2, s_2). The CEO is of high expected ability, as is the successor, but then the CEO leaves for exogenous reasons τ_λ and the firm moves to $(0, s_2)$. The board decides to act by promoting the successor and hiring a new successor, which moves the firm to (s_2, e).

3. (c_3, s_3): The firm starts at (c_3, s_3). The board receives negative news about the successor and CEO, which drives down the expected abilities to (c_3', s_3'). At this point, the CEO is no longer sufficiently able and the board replaces the CEO with an external candidate, which moves the firm to (e, s_3').

II Model Analysis

In this section, we analyse several predictions of the model about the firm's succession planning.

A CEO Ability and Equity Value

We first study how the CEO's and the successor's expected ability affects equity value. As the following proposition shows, the firm is always better off by having a CEO and a successor of a higher expected ability.

Proposition 1 (Equity Value and CEO and Successor Expected Ability)**.** *The equity value $V(c, s)$ is (weakly) increasing in the CEO's expected ability c and in the successor's expected ability s.*

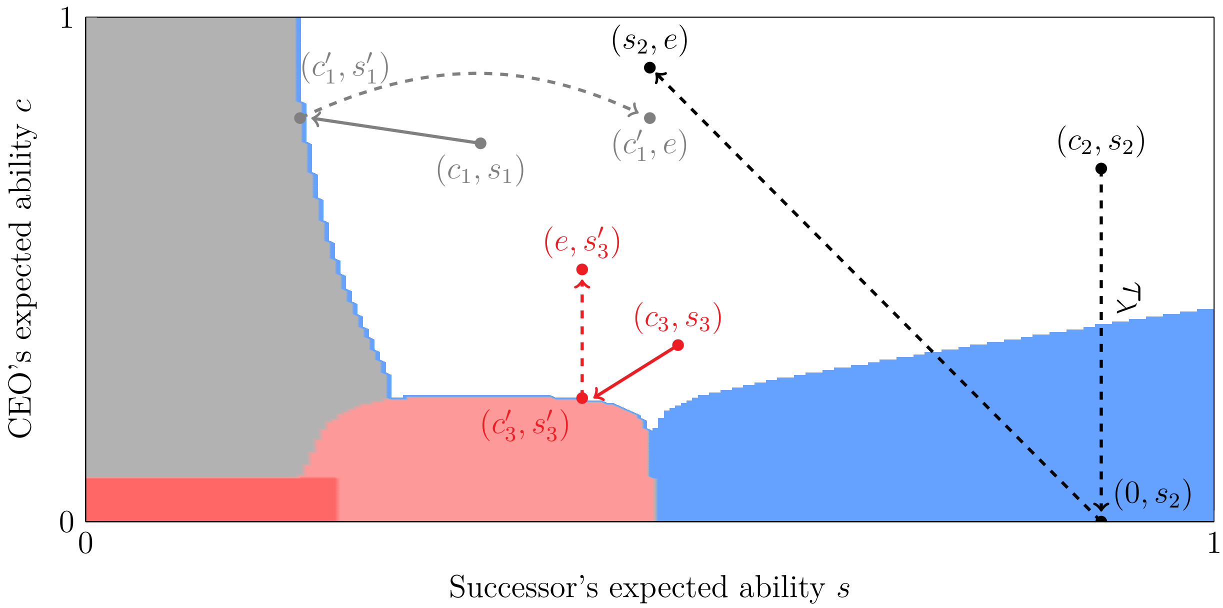

Figure 3: **Different Sample Paths**. The figure shows the solution of the model and state variables (c, s) dynamics given the parameters $(r, \lambda, \phi^c, \phi^s, K, e, \Phi) = (4\%, 10\%, 0.5, 0.5, 0.4, 0.5, 0.5)$. Appendix B describes the numerical algorithm used to solve the model.

In our model, more able CEOs and successors allow the firm to generate higher cash flows, which increases the firm's equity value. This result is consistent with existing empirical evidence (Bertrand and Schoar, 2003; Bandiera et al., 2020; Bennedsen et al., 2020; Jenter et al., 2021) documenting that CEO ability is positively related to equity value. An additional prediction of our model is that equity value should also increase in the successor's expected ability.

B Departures

We next focus on analyzing when executives depart from the firm. We establish that the CEO's departure policy comes in a threshold form. If the board wants to replace the CEO due to insufficient ability, then the board will also replace any worse CEO.

Proposition 2 (CEO Departures)**.** *There exists a threshold* $\underline{c}(s)$ *such that the board (weakly) wants the CEO to leave if and only if* $c \leq \underline{c}(s)$*.*

$$V(c,s) = \max\{V(e,s) - K - \Phi, V(s,0) - K\} \quad \Leftrightarrow \quad \forall c \leq \underline{c}(s).$$

The successor's departure policy also comes in a threshold form. If the board wants to replace the successor due to insufficient ability, then the board will also replace any worse successor.

Proposition 3 (Successor Departures)**.** *There exists a threshold* $\underline{s}(c)$ *such that the board (weakly) wants the successor to leave if and only if* $s \leq \underline{s}(c)$*.*

$$V(c,s) = V(c,e) - \Phi \quad \Leftrightarrow \quad s \leq \underline{s}(c).$$

Figure 4 shows these departure thresholds given the parameters of Figure 2 and documents that these two departure thresholds—$\underline{s}(c)$ and $\underline{c}(s)$—effectively split the parameter space. In the upper part, above $\underline{s}(c)$ and $\underline{c}(s)$, the board does not reshuffle the management, while below it the board changes the firm's management either by replacing the CEO or the successor.

C Who Becomes The New CEO?

We next focus on who becomes the new CEO following a management reshuffle. In particular, we want to understand when an external candidate is more likely to replace the CEO than an internal one. We define an *external succession* as the scenario in which the board appoints an external candidate to directly replace the firm's CEO, $c = e$.[18] If the board promotes an internal successor then we call this an *internal succession*, $c = s$. We show that the prevalence of internal and external successions crucially depends on learning about the

[18]By this we mean that the external candidate is hired at time t and becomes the CEO at time t.

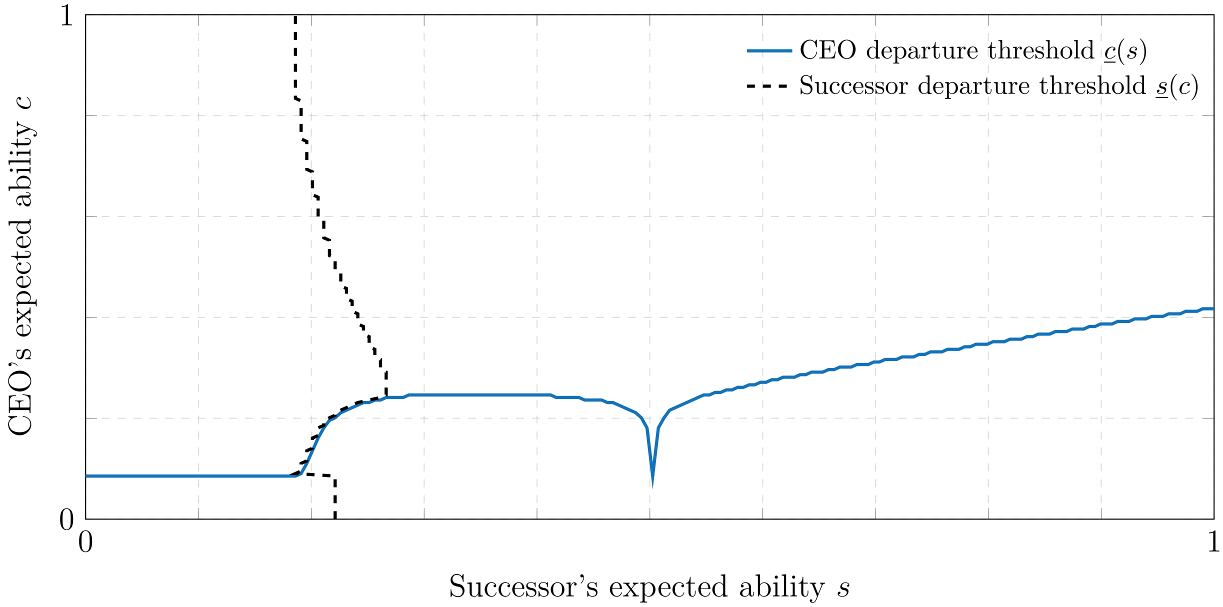

Figure 4: **CEO and Successor Departure Thresholds**. The figure shows the CEO departure threshold $\underline{c}(s)$ and the successor departure threshold $\underline{s}(c)$ of the model given the parameters $(r, \lambda, \phi^c, \phi^s, K, e, \Phi) = (4\%, 10\%, 0.5, 0.5, 0.4, 0.5, 0.5)$. Appendix B describes the numerical algorithm used to solve the model.

successor's ability. As we demonstrate in the following proposition, without learning about the successor's ability ($\phi^s = 0$), and when the firm has no current successor ($s = 0$), there is no difference between hiring a new CEO internally or externally in terms of the expected cash flows they would generate as CEO. In this case, to delay the search cost, the board optimally hires external candidates to directly become the CEO instead of hiring an internal successor early on.

Proposition 4 (No Learning)**.** *Assume that there is no learning about any successor, $\phi^s = 0$, there are cost of searching for an external candidate, $\Phi > 0$, and there is no current successor, $s = 0$. Then in the future there will only be external successions.*

Figure 5 highlights the succession dynamics in this case. Because there is no successor, the firm remains at $s = 0$. The CEO leaves for exogenous reasons at τ_λ or when the CEO's expected ability drops to $\underline{c}(0)$ in either case the firm hires an external candidate to become the new CEO. From the figure it also becomes clear that the firm never hires a successor. The figure gives an example of the succession dynamics in the model. The firm starts at $(e, 0)$, receives positive news about the CEO and moves to $(c', 0)$, after which the CEO leaves for exogenous reasons and gets replaced, so that the firm ends up at $(e, 0)$ again. There will only be external successions in this case.

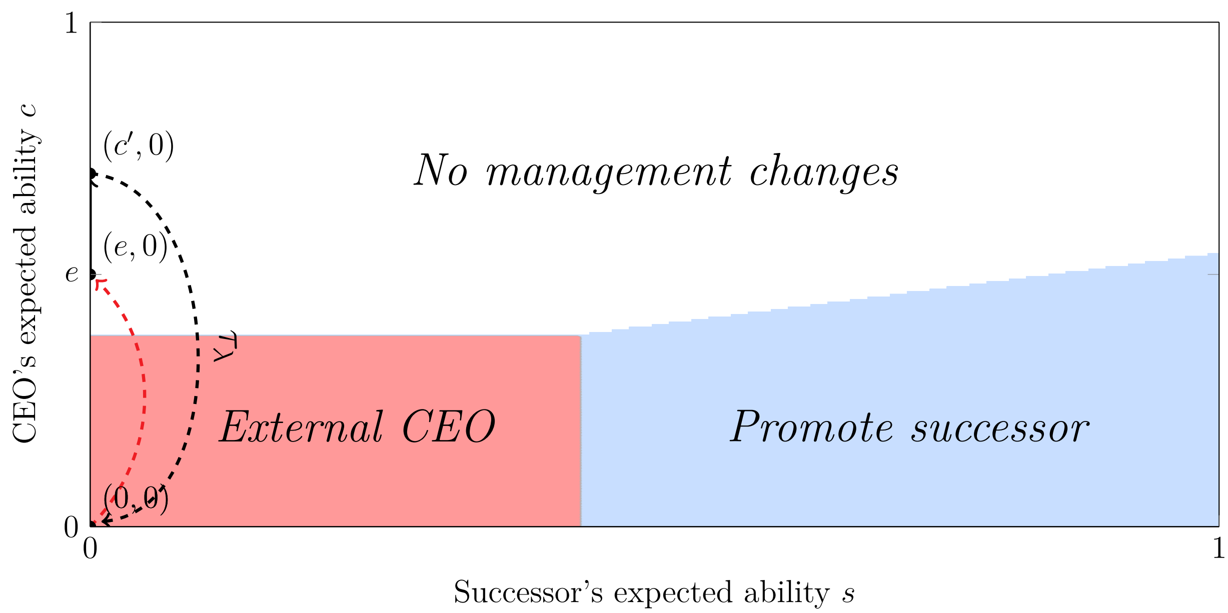

Figure 5: **No Learning Leads to External Successions**. The figure shows the solution of the model given the parameters $(r, \lambda, \phi^c, \phi^s, K, e, \Phi) = (4\%, 10\%, 0, 0, 0.4, 0.5, 0.5)$. Appendix B describes the numerical algorithm used to solve the model.

On the other hand, when there are no search costs, $\Phi = 0$, and when there is learning about the successor, $\phi^s > 0$, then the firm's successor is almost surely better than the external candidates. The reason is that when the firm does not have to incur search costs, an inferior successor $S_t < e$ would be directly replaced at no cost by an external candidate. Consequently, the successor's expected ability S_t is higher than the external candidates' expected ability e, giving the board an incentive to promote the successor.

Proposition 5 (No Search Cost)**.** *Assume that there is learning, $\phi^s > 0$, there are no costs of searching for an external candidate, $\Phi = 0$, the CEO contributes more to the equity value than the successor, $c_1 \geq c_2 \Rightarrow V(c_1, c_2) \geq V(c_2, c_1)$, and the firm employs a successor of ability $s \geq e$. Then in the future there will only be internal successions.*[19]

Figure 6 highlights the succession dynamics in this case. The gray area acts as a reflective boundary due to the fact that the board replaces a successor as soon as $S_t < e$. Therefore, the only way for the firm to replace the CEO is via the blue region, in which the board promotes the successor to CEO and hires a new successor. Therefore, there are only internal successions.

Importantly, Propositions 4 and 5 hold true even in a labor market equilibrium in which the ability of the external candidates is endogenous $e^*(r, \lambda, \phi^c, \phi^s, K, \Phi) \in [0, 1]$. The reason is that both propositions do not depend on a specific value for the expected ability of external candidates e and therefore also hold for $e^*(r, \lambda, \phi^c, \phi^s = 0, K, \Phi > 0)$ in Proposition 4 and for $e^*(r, \lambda, \phi^c, \phi^s > 0, K, \Phi = 0)$ in Proposition 5.[20]

Some of the main results of our paper follow from Propositions 4 and 5. First, our model can rationalize the fact that firms appear to prefer hiring internal successors, as documented by Parrino (1997), Huson et al. (2004) or Cziraki and Jenter (2022). Second, Propositions 4 and 5 demonstrate (in limiting cases) that firms allow for more external successions when they have to incur higher search costs ($\Phi \uparrow$) or when they learn more slowly about the successor ($\phi^s \downarrow$).[21]

[19]We assume that if the board is indifferent between appointing the successor or an external candidate to CEO then it appoints the successor, and if the board is indifferent between hiring a new successor or not, then it hires a new successor. Furthermore, we assume that the timing of information arrival and actions at time t is as follows: *i*) τ_λ arrives or not, *ii*) the board decides who to appoint as CEO, *iii*) news about the CEO and the successor arrives, and *iv*) the board decides who becomes the successor.

[20]Of course, the assumptions stated in Proposition 4 need to hold for $e^*(r, \lambda, \phi^c, \phi^s = 0, K, \Phi > 0)$ and the assumptions stated in Proposition 5 need to hold for $e^*(r, \lambda, \phi^c, \phi^s > 0, K, \Phi = 0)$.

[21]Assuming that the learning in our model is about firm-specific human capital and that this human capital is less important for PE-backed firms who rely more on general managerial ability ($\phi^s \downarrow$) then our model can explain the lower incidence of internal succession in PE-backed firms that Gompers et al. (2023) find.

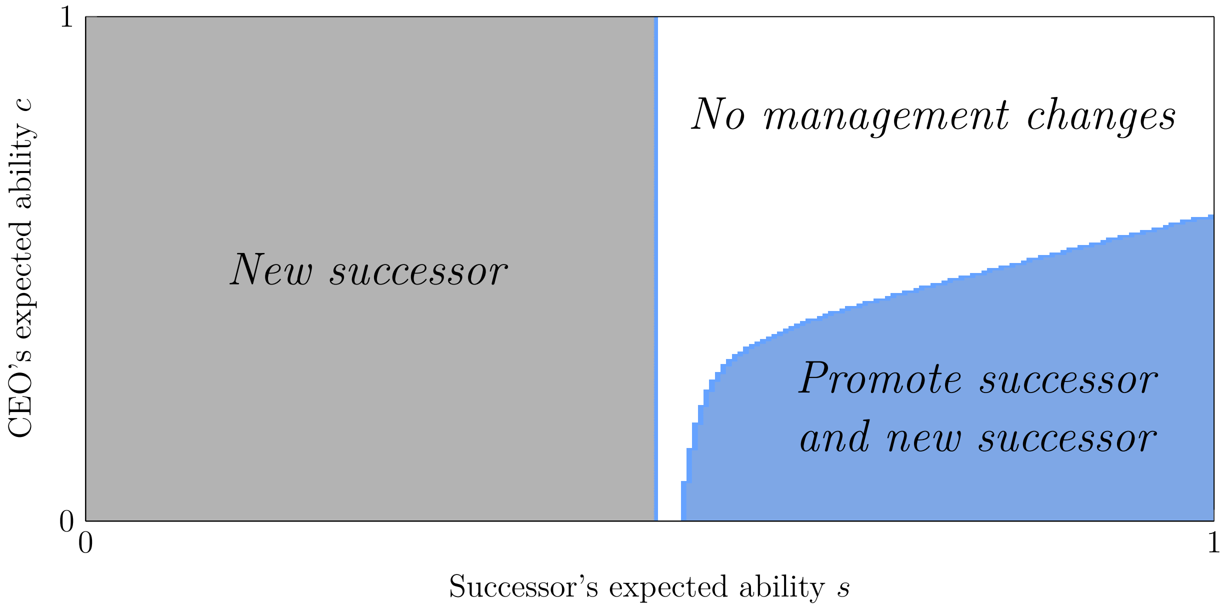

Figure 6: **No Search Cost Leads to Internal Successions**. The figure shows the solution of the model given the parameters $(r, \lambda, \phi^c, \phi^s, K, e, \Phi) = (4\%, 10\%, 0.5, 0.5, 0.4, 0.5, 0)$. Appendix B describes the numerical algorithm used to solve the model.

Additionally, we argue that higher levels of internal successions do not necessarily mean that the market for CEOs is inefficient. In our model, lower search costs ($\Phi \downarrow$) have two effects. First, they make hiring external candidates less expensive, so that external succession is more likely. Second, lower search costs are associated with a less costly replacement of the successor, which results in the firm employing successors of higher expected ability and therefore increases the incidence of internal successions. Proposition 5 shows that this second effect dominates as the labor market becomes frictionless. Therefore, the large extent of internal successions observed empirically is also consistent with a more efficient labor market instead of other explanations such as agency conflicts or behavioral biases (e.g., Hermalin and Weisbach, 1998).

D Succession Planning

Our model also allows us to study firms' optimal succession policies. As shown by Figure 1 and Equation (1), it is possible that firms are optimally run without a CEO, $V(0, S_\tau)$, or without a successor, $V(S_\tau, 0)$. In both cases, the board's succession strategy maximizes the equity value. Therefore, the absence of a successor and the apparent absence of succession planning may not necessarily indicate that the firm is badly run, as suggested by prior empirical work (Fernández-Aráoz et al., 2021).

The firm might not appoint a new CEO for two reasons. First, because it is expensive for firms to appoint CEOs. Second, because appointing a subpar CEO today is costly as it increases the effective cost of hiring a new CEO in the future. The reason is that the firm has to forgo future cash flows generated by this subpar CEO when letting her go decreasing the benefits of appointing a new CEO,

$$\underbrace{\max\{V(s,0), V(e,s) - \Phi\} - K - V(c,s)}_{\textit{Benefits of new CEO given current CEO}} \leq \underbrace{\max\{V(s,0), V(e,s) - \Phi\} - K - V(0,s).}_{\textit{Benefits of new CEO given no current CEO}}$$

The same reasoning causes the board's CEO departure strategy to be a threshold one, see Proposition 2.

The following proposition shows that the cost of appointing a new CEO K plays an important role in this mechanism. When this cost is too high, the board strategically delays appointing a new CEO. Furthermore, the more able the successor, the higher the cost needs to be to induce the board to forgo appointing a new CEO.

Proposition 6 (Delayed Succession)**.** *For any successor of expected ability s, there exists a replacement cost $\bar{K}(s) \leq \frac{\max\{s,e\}}{r+\lambda}$ with $\bar{K}'(s) \geq 0$ such that for $K > \bar{K}(s)$ the board prefers to not directly appoint a new CEO*

$$\max\{V(s,0) - K, V(e,s) - K - \Phi\} < V(0,s).$$

Figure 7 shows the board's optimal actions when the replacement cost K is high. When the CEO leaves for an exogenous reason and the successor is not too able, then the board will not appoint a new CEO until the successor's expected ability reaches the blue region. The board thus optimally delays succession.

These results shed light on the apparent absence of succession planning found in many corporations (Cvijanović et al., 2022; Larcker et al., 2022) and on the long delays in appointing a new CEO, which can also be optimal for firms as Rivolta (2018) and Gabarro et al. (2022) find. If in practice smaller firms face relatively higher CEO replacement costs then Proposition 6 implies that succession planning—a direct replacement of a departing CEO—is value destroying for smaller firms while it is value-enhancing for larger firms. This result is consistent with: *i*) the evidence of McConnell and Qi (2022) who show that succession planning disclosure destroys value for smaller firms and increases the value of larger firms, *ii*) Cvijanović et al. (2022) who find that larger firms are more likely to have a succession plans, and *iii*) Gabarro et al. (2022) who show that smaller firms are more likely to have protracted successions.

III Managerial Entrenchment and Sabotage

Prior literature has suggested that CEO entrenchment is an important determinant of corporate policies (Berger et al., 1997; Nikolov and Whited, 2014). In this section, we want to understand when the CEO decides to become entrenched and how the board optimally responds to this action. To this end, we extend the baseline model by allowing the CEO to become endogenously entrenched by engaging in a *sabotage* of the successor (Salop and Scheffman, 1983; Lazear, 1989), consistent with the empirical evidence of (Boeker, 1992; Cannella and Shen, 2001; Zhang, 2006). By doing so, the CEO makes the successor worse-off, so that she is less likely to be replaced by the successor. We show that compensation plays a crucial role in determining the CEO's incentives to sabotage and become entrenched

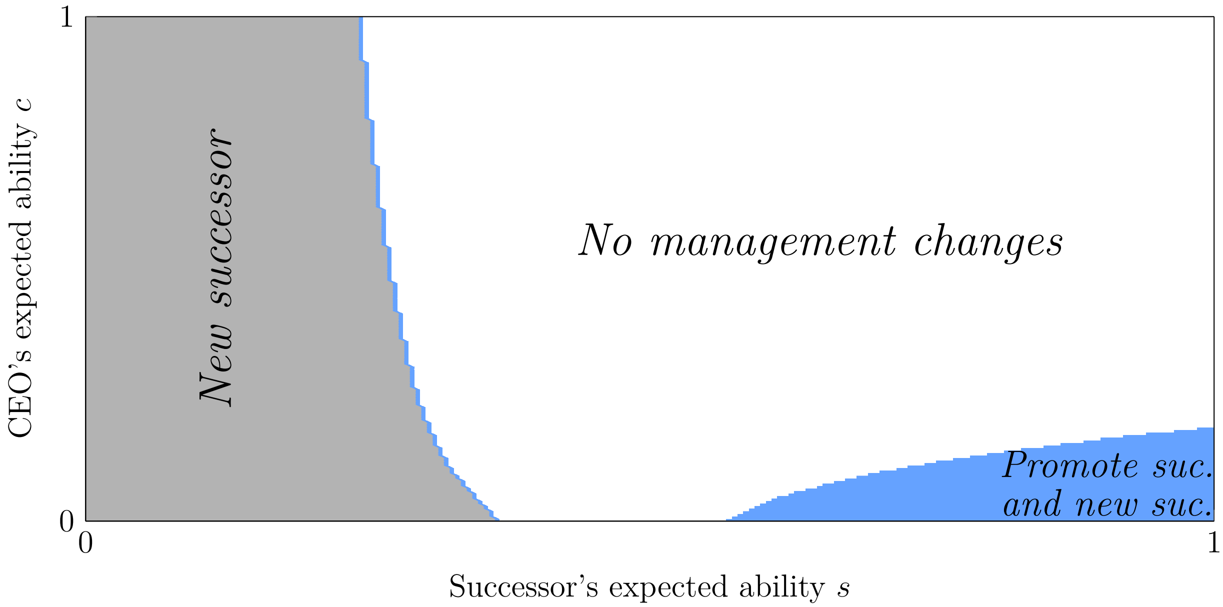

Figure 7: **Delayed Succession**. The figure shows the solution of the model given the parameters $(r, \lambda, \phi^c, \phi^s, K, e, \Phi) = (4\%, 10\%, 0.5, 0.5, 2.5, 0.5, 0.35)$. Appendix B describes the numerical algorithm used to solve the model.

and that the CEO's attempts to become entrenched can sometimes backfire and result in the CEO getting replaced more easily.

In the extended model, the CEO can sabotage the successor by negatively impacting the successor's ability. In practice, the CEO could, for example, not collaborate with the successor or not engage in mentoring, which would effectively make the successor less prepared and thus less capable in running the firm in the future. For example, Cannella and Shen (2001), Bower (2012), and Berns and Klarner (2017) argue that incumbent CEOs play an important role in the succession process. The CEO cannot sabotage external candidates because she has little direct interactions with them.

We assume that the CEO has the same information as the board and thus does not know her own ability. At each time t, the CEO selects a level of sabotage $f_t \in [0, \bar{f}]$ to maximize her payoff, where $f_t = 0$ means that the CEO does not sabotage the successor. The dynamics of the successor's expected ability given the choice of sabotage f_t are

$$dS_t = -f_t S_t dt + \phi^s S_t(1 - S_t)dB_t^s.$$

These dynamics imply that when the CEO chooses a level of sabotage f_t, it results in making a high-ability successor a low-ability successor with intensity $f_t dt$. Therefore, this level of sabotage lowers the expected ability of the successor by $-f_t S_t dt$.

The CEO's incentives to sabotage the successor depend on the CEO's compensation, which consists of two parts: a profit-based part and an equity stake, similar to Nikolov and Whited (2014). We assume that the CEO, just as shareholders, is risk-neutral and discounts cash flows at the rate $r > 0$. The CEO receives a fraction $\alpha \geq 0$ of the firm's profits when being in office, which amounts to $\alpha W(c, s)$. The results presented later would also hold if instead of a profit share part the CEO received a fixed wage or a utility flow from being the CEO. Notably, both forms of compensation increase with the CEO's tenure. The CEO is also granted a fraction $\beta \geq 0$ of the firm's equity $\beta V(c, s)$. We assume that the CEO's equity vests when leaving the firm (Edmans et al., 2017). This implies that the CEO's total expected discounted compensation is

$$\alpha W(c, s) + \beta V(c, s). \tag{2}$$

At any time, the CEO's expected future compensation is also given by Equation (2). We normalized the CEO's outside option to zero. In practice, CEO's personal income drops by around 40% after a forced turnover (Nielsen, 2016).

The value of the firm's cash flows until the CEO leaves is given by

$$W(c, s) = \mathbb{E}_{c,s}\left[\int_0^\tau e^{-rt}dX_t + \mathbb{I}_{\{\tau=\tau_E\}}e^{-r\tau}\mathbb{I}_{\{V(C_\tau,e)>\max(V(e,S_\tau)-K,V(S_\tau,e)-K)\}}W(C_\tau, e)\right].$$

The first term represents the profits that the firm generates from now until the moment when either the CEO or the successor gets replaced. The second term reflects the profits generated by the current CEO in case when only the successor gets replaced.

This problem corresponds to a dynamic game between the board and the current (and future) CEOs. The reason is that the CEO's optimal sabotage of the successor depends on the firm's succession policy, and vice versa. We study Markov Perfect Equilibria in (c, s) in this game (Maskin and Tirole, 2001). This means that *i*) the optimal sabotage and succession policies are a function of (c, s), *ii*) the CEO's sabotage policy is optimal given the firm's succession policy, and *iii*) the firm's succession policy is optimal given the CEO's sabotage policy.

In equilibrium, the CEO picks the level of sabotage $\{f_t\}_{t\geq 0}$ to maximize her expected discounted payoff. The impact of the CEO's sabotage f_t on her compensation is

$$-\left(\alpha W_s(c,s) + \beta V_s(c,s)\right) f_t S_t dt. \tag{3}$$

Therefore, the optimal level of sabotage is

$$f_t = \begin{cases} \bar{f} & \frac{\alpha}{\beta} < -\frac{V_s(c,s)}{W_s(c,s)} \\ 0 & \frac{\alpha}{\beta} \geq -\frac{V_s(c,s)}{W_s(c,s)} \end{cases}. \tag{4}$$

From Equation (4) it becomes clear that the CEO's compensation, as summarized by the fraction of the profit sharing part over the equity stake $\frac{\alpha}{\beta}$, is an important determinant of the level of sabotage.

As the following proposition shows, when given only the equity-based compensation, the CEO tries to maximize the firm's equity value and therefore does not sabotage the successor since it negatively impacts the equity value. As a consequence, the CEO endogenously does not become entrenched.

Proposition 7 (Equity Compensation and No Sabotage)**.** *When the CEO only receives* *equity compensation, $\alpha = 0$ and $\beta > 0$. In any equilibrium, the CEO does not sabotage the successor $f_t = 0$ and therefore does not become entrenched.*[22]

On the other hand, when the CEO receives only the profit-based compensation, then she is incentivized to stay longer and, as a consequence, the CEO will sabotage any sufficiently-abled successor to prevent getting replaced.

Proposition 8 (Profit-Based Compensation and Sabotage)**.** *Assume the CEO only receives profit-based compensation, $\alpha > 0$ and $\beta = 0$, and $\phi^c W_{cc}(c, s) \geq 0$. Given an equilibrium and a CEO and successor (c, s). This CEO sabotages this successor if and only if $S_t \geq \hat{s}(C_t|c, s)$.*[23]

The results in Propositions 7 and 8 show that CEO compensation plays a crucial role in determining sabotage and entrenchment in equilibrium. CEOs whose compensation is more equity-based should have less incentives to sabotage their successors and are therefore less entrenched. The same holds true for CEOs facing weaker successors.

How should the board optimally respond to a CEO who sabotages the successor? In Figure 8, we take the baseline parameter values from Figure 2 and assume that the firm is run by a CEO (and future CEOs) who always sabotages the successor(s). Figure 8 shows that the board responds in two distinct ways to the CEO's actions.[24] First, the board alters the hiring policy by delaying replacing a successor (as compared to Figure 2). The reason is that the CEO will also sabotage future successors, which results in the board being less likely to hire one today. This change in the board's hiring policy negatively impacts the successor's expected ability above and beyond the direct effect of the CEO's sabotage, thereby further increasing managerial entrenchment. Second, the board alters the promotion policy and replaces the CEO sooner. Knowing that the CEO sabotages the successor lowers

[22]If the CEO is indifferent between sabotaging or not sabotaging the successor then she decides not to sabotage the successor.

[23]If the CEO is indifferent, then we assume the CEO sabotages the successor.

[24]This figure also shows that it is not always optimal for the CEO to sabotage the successor. In the region just to the right of the red-colored area, sabotage hurts the CEO's compensation because it lowers both the firm's equity value and the CEO's expected tenure.

the option value of delaying succession. In response, the board changes the promotion policy and replaces the CEO with the successor earlier. Trying to become entrenched can thus backfire for the CEO, since the board anticipates her actions and acts accordingly.

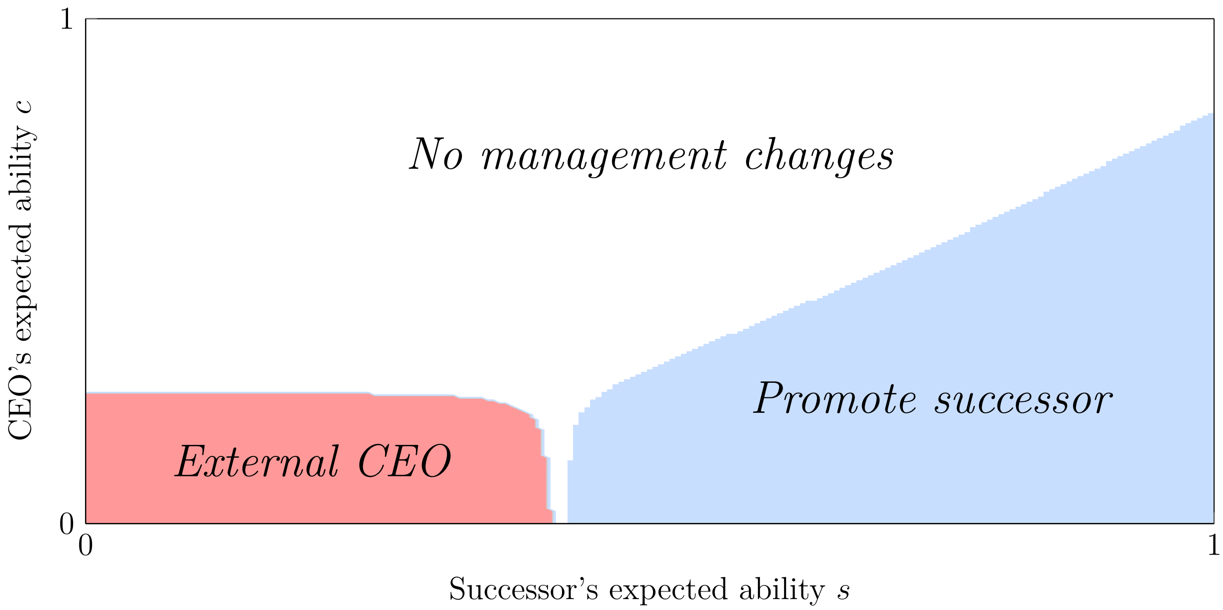

Figure 8: **The Firm's Response to Sabotage**. The figure shows the solution of the model in which the CEO always sabotages the successor given the parameters $(r, \lambda, \phi^c, \phi^s, K, e, \Phi, \bar{f}) = (4\%, 10\%, 0.5, 0.5, 0.4, 0.5, 0.5, 15\%)$. Appendix B describes the numerical algorithm used to solve the model.

In practice, the CEO can also help foster executive talent within the firm. This mentoring by the CEO is an important part of the succession process and helps the successor develop herself into a future CEO (Moats and DeNicola, 2021). We can extend our model by allowing the CEO to mentor the successor. The CEO would select a level of mentoring $m_t \in [0, \bar{m}]$ to maximize her payoff and the dynamics of the successor's expected ability given the choice of mentoring m_t would be $dS_t = m_t(1 - S_t)dt + \phi^s S_t(1 - S_t)dB_t^s$.

In a setup with mentoring, we can derive several results. First, we can demonstrate that equity compensation would incentivize the CEO to mentor the successor as it increases the firm's equity value. Second, we can prove that profit-based compensation would make it more likely for the CEO to mentor the successor if and only if the successor is sufficiently weak. The reason is that mentoring a too able successor would increase the likelihood of the CEO being replaced while mentoring a less able successor would decrease the likelihood of this successor being replaced by a more able one. Third, the firm would respond to the CEO mentoring the successor by lowering the chances of replacing the successor, which would prolong the CEO's tenure.

IV Conclusion

We develop a dynamic model of CEO succession. In the model, the board learns about the ability of the CEO and successor and can replace the CEO by the successor or search for an external candidate. As a consequence, the presence of a successor within the firm is akin to a real option.

We use our model to rationalize the prevalence of internal CEO successions, the apparent absence of succession planning, and the delays in appointing new CEOs. The model also implies that, as the labor market for executives becomes more efficient, the fraction of successors hired externally becomes smaller. Finally, we show that succession planning can foster managerial entrenchment but can also result in the CEO getting fired more easily. Overall, our analysis highlights the importance of succession planning in shaping corporate decisions.

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Appendix

The first appendix (Appendix A) contains the proofs and the second appendix (Appendix B) the numerical implementation of the baseline model.

A Proofs

Given the result in Corollary 1, all proofs expect for the proof of Proposition 8 are done for the case $\mu = 0$ without loss of generality.

Proof of Proposition 1. Given the board's beliefs, we have that $dX_t = C_t dt + \frac{1}{\phi^c} dB_t^c$. Assume that $c' > c$. Given a sample path of $B_t^c(\omega)$, we have that for the current CEO $C_t'(\omega) > C_t(\omega)$.

Let $\tilde{V}(c', s)$ be the equity value when the board acts as if the current CEO only has prior expected ability c instead of c'. Under this policy, the cash flows of $\tilde{V}(c', s)$ and $V(c, s)$ are the same except for the ones generated by the current CEO which are strictly higher since $C_t'(\omega) > C_t(\omega)$. As a consequence,

$$V(c, s) \leq \tilde{V}(c', s) \leq V(c', s)$$

where the first inequality follows from the fact that all future expected cash flows are weakly larger if the current CEO has expected ability $c' > c$ and the second inequality follows from the fact that the firm's optimal policies maximize its equity value.

Similar arguments as above imply that when $s' > s$ then $V(c, s) \leq V(c, s')$. □

Proof of Proposition 2. Given s, if the CEO does not depart for any $c \in [0, 1]$ then $\underline{c}(s) < 0$ and we are done. Otherwise, let $\underline{c}(s) \geq 0$ be the largest value of c such that the CEO departs. We know that $V(c, s) \geq \max\{V(e, s) - \Phi - K, V(s, 0) - K\}$ because the board maximizes the equity value.

Assume the result is not true then there would exist a $c < \underline{c}(s)$ such that $V(c, s) > \max\{V(e, s) - \Phi - K, V(s, 0) - K\} = V(\underline{c}(s), s)$, which contradicts the fact that the equity value is weakly increasing in c (Proposition 1).[25] □

Proof of Proposition 3. Given c, if the successor does not depart for any $s \in [0, 1]$ then $\underline{s}(c) < 0$ and we are done. Otherwise, let $\underline{s}(c) \geq 0$ be the largest value of s such that the successor departs. We know that $V(c, s) \geq V(c, e) - \Phi$ because the board maximizes the equity value.

Assume the result is not true then there would exist an $s < \underline{s}(c)$ such that $V(c, s) > V(c, e) - \Phi = V(c, \underline{s}(c))$, which contradicts the fact that the equity value is weakly increasing in s (Proposition 1). □

[25] Observe that the board would never strictly prefer to let the CEO go without replacing her as the expected cash flows she generates are non-negative $C_t dt \geq 0$.

Proof of Proposition 4. We want to show that it is suboptimal for the board to hire a successor given that the firm has no successor today, which guarantees that all successions are external successions.

Given that $\phi_s = 0$, there is no learning about the successor's ability and therefore the successor's expected ability remains at s.

Assume the firm has no current successor $s = 0$ and the current CEO is of expected ability $c \geq 0$. The equity value is $V(c, 0)$. Suppose that it is optimal for the board to hire an external candidate today to become the successor. This implies that $V(c, 0) = V(c, e) - \Phi$.

Proposition 2 implies that the CEO gets replaced as as soon as $C_t \leq \underline{c}(e)$. There are two cases.

1. $c \leq \underline{c}(e)$. In this case, the board (weakly) prefers to replace the CEO and therefore $V(c, e) = \max\{V(e, 0) - K, V(e, e) - \Phi - K\}$. There are now two situations.

   (a) $V(c, e) = V(e, 0) - K$ and therefore $V(c, 0) = V(e, 0) - K - \Phi$, which implies that the board directly hired the external candidate to become CEO and therefore does not actually employ a successor.

   (b) $V(c, e) = V(e, e) - \Phi - K$ and therefore $V(c, 0) = V(e, e) - 2\Phi - K$, which implies that the board directly hired two external candidates, one to become CEO and the other to become the successor. Given that the ordering of hiring the external candidates is irrelevant,

   $$V(e, e) - \Phi = V(e, 0).$$

   Suppose that $e \leq \underline{c}(e)$, then it would be (weakly) optimal for the board to replace the CEO

   $$V(e, e) = \max\{V(e, 0) - K, V(e, e) - K - \Phi\} = V(e, e) - K - \Phi,$$

   which cannot be true as $K > 0$ and $\Phi > 0$. Therefore, $e > \underline{c}(e)$.

   Let $\tau_C = \inf\{t > 0 | C_t \leq \underline{c}(e)\}$ be the time at which the CEO gets replaced for endogenous reasons. The CEO can also leave for exogenous reasons at τ_λ. After the CEO departs (at either τ_C or τ_λ), but before any other actions are taken, the equity value is $V(0, e)$. The following inequalities then hold true

   $$\begin{aligned} V(e, 0) &= V(e, e) - \Phi \\ &= \mathbb{E}_{e,e}\left[\int_0^{\min\{\tau_C, \tau_\lambda\}} e^{-rt} dX_t + e^{-r \min\{\tau_C, \tau_\lambda\}} V(0, e)\right] - \Phi \\ &< \mathbb{E}_{e,e}\left[\int_0^{\min\{\tau_C, \tau_\lambda\}} e^{-rt} dX_t + e^{-r \min\{\tau_C, \tau_\lambda\}} (V(0, e) - \Phi)\right]. \end{aligned}$$

The first equality follows from the fact that hiring a successor today is optimal and the second equality follows from the expected cash flows the firm receives until $\min\{\tau_C, \tau_\lambda\}$. The inequality follows from the fact that $\Phi > 0$, $r > 0$, and $\min\{\tau_C, \tau_\lambda\} > 0$. But this inequality implies that delaying hiring the successor until $\min\{\tau_C, \tau_\lambda\}$ increases the equity value, which contradicts the optimality of hiring a successor today.

2. $c > \underline{c}(e)$. Let $\tau_C = \inf\{t > 0 | C_t \leq \underline{c}(e)\}$ be the time at which the CEO gets replaced for endogenous reasons. The CEO can also leave for exogenous reasons at τ_λ. After the CEO departs (at either τ_C or τ_λ), but before any other actions are taken, the equity value is $V(0, e)$. The following inequalities then hold true

$$
\begin{aligned}
V(c, 0) &= V(c, e) - \Phi \\
&= \mathbb{E}_{c,e}\left[\int_0^{\min\{\tau_C,\tau_\lambda\}} e^{-rt} dX_t + e^{-r\min\{\tau_C,\tau_\lambda\}} V(0, e)\right] - \Phi \\
&< \mathbb{E}_{c,e}\left[\int_0^{\min\{\tau_C,\tau_\lambda\}} e^{-rt} dX_t + e^{-r\min\{\tau_C,\tau_\lambda\}} (V(0, e) - \Phi)\right].
\end{aligned}
$$

The first equality follows from the fact that hiring a successor today is optimal and the second equality follows from the expected cash flows the firm receives until $\min\{\tau_C, \tau_\lambda\}$. The inequality follows from the fact that $\Phi > 0$, $r > 0$, and $\min\{\tau_C, \tau_\lambda\} > 0$. But this inequality implies that delaying hiring the successor until $\min\{\tau_C, \tau_\lambda\}$ increases the equity value, which contradicts the optimality of hiring a successor today.

The board will thus optimally never hire (and therefore promote) a successor and as a consequence all successions are external successions. □

Proof of Proposition 5. See footnote 19 for additional assumptions. From Proposition 1 it follows that $V_s(c, s) \geq 0$. As a consequence for any $s \leq e$, $V(c, s) - \Phi = V(c, s) \leq V(c, e)$ and therefore the board replaces the successor as soon as $s \leq e$. As a result, the firm's successor has an expected ability $s \geq e$.

For $s > e$, if it is ever (strictly) optimal to hire an external successor then we must have that $V(s, e) < V(e, s)$ but since $s > e$ and $c_1 \geq c_2 \Rightarrow V(c_1, c_2) \geq V(c_2, c_1)$ this can't be true. Therefore, there are only internal successions for $s > e$.

At $s = e$, the board replaces the CEO with the successor who is of type $s = e$ as no news has arrived yet about the successor before the CEO replacement decision is made, see the timing we assume at each time t in footnote 19. Therefore, at $s = e$ only internal successions take place. □

Proof of Proposition 6. Let $\tilde{V}(0, s)$ be the equity value when the board acts as if its current CEO is of expected ability c instead of 0. The difference in cash flows between $V(c, s)$ and

$\tilde{V}(0,s)$ is

$$\left(C_t dt + \frac{1}{\phi^c} dB_t^c\right) - \left(0 + \frac{1}{\phi^c} dB_t^c\right) = C_t dt \geq 0$$

for as long as the current CEO is employed. Therefore,

$$\frac{c}{r+\lambda} = \mathbb{E}_{c,s}\left[\int_0^{\tau_\lambda} e^{-rt} c dt\right] = \mathbb{E}_{c,s}\left[\int_0^{\tau_\lambda} e^{-rt} C_t dt\right] \geq V(c,s) - \tilde{V}(0,s) \geq V(c,s) - V(0,s). \quad \text{(A.1)}$$

The second equality follows from the fact that C_t is a martingale. The first inequality follows from the difference in cash flows between $V(c,s)$ and $\tilde{V}(0,s)$ and the fact that the current CEO is employed for at most τ_λ. The second inequality follows from the fact that the firm's optimal policies maximize its equity value

Assume $K > \tilde{K}(s) = \frac{\max\{e,s\}}{r+\lambda}$. From equation (A.1), Proposition 1, and the fact that $\Phi \geq 0$ it then follows that

$$V(s,0) - K \leq V(s,s) - K < V(0,s),$$
$$V(e,s) - K - \Phi \leq V(e,s) - K < V(0,s).$$

Therefore, the board has no incentive to either promote the current successor or hire an external candidate to become the CEO when $K > \tilde{K}(s)$ and $\tilde{K}'(s) \geq 0$. From this it directly follows that the function $\bar{K}(s)$ exists. □

Proof of Proposition 7. Given a Markovian sabotaging strategy $f(c,s)$ and $c' = c$, for any sample path $(B_t^c(\omega), B_t^s(\omega))$ if $s' > s$ then for the current successors s' and s it holds that $S_t'(\omega) \geq S_t(\omega)$.[26] If the successors s' and s would get promoted at the same time then this result implies that when they are CEOs $C_t'(\omega) \geq C_t(\omega)$.

Let $\tilde{V}(c,s')$ be the equity value assuming the board acts as if the current successor is of expected ability s instead s'. In that case

$$V(c,s) \leq \tilde{V}(c,s') \leq V(c,s').$$

The first inequality follows from the fact that the cash flows are at least as large for $\tilde{V}(c,s')$ as for $V(c,s)$ given that when the current successors s' and s become CEOs (at the same time) then $C_t'(\omega) \geq C_t(\omega)$. The second inequality follows from the fact that $V(c,s)$ maximizes the equity value. Therefore, $V_s(c,s) \geq 0$.

The CEO's compensation is $\beta V(c,s)$. The impact of the CEO's sabotaging at time t on

[26]The sample paths of $(C_{\tilde{t}}'(\omega), S_{\tilde{t}}'((\omega))$ and $(C_{\tilde{t}}((\omega), S_{\tilde{t}}((\omega))$ are continuous. Observe that $C_t'(\omega) = C_t(\omega)$ for any t. If for some t $S_t'(\omega) = S_t(\omega)$ then for any $\tilde{t} > t$ $(C_{\tilde{t}}'(\omega), S_{\tilde{t}}'((\omega)) = (C_{\tilde{t}}((\omega), S_{\tilde{t}}((\omega))$ as the sabotaging and shocks they face are the same. Therefore, $S_t'(\omega) \geq S_t(\omega)$.

her compensation is

$$\max_{f_t \in [0,\bar{f}]} -f_t \beta V_s(c, S_t) S_t dt \leq 0,$$

which is maximized when $f_t = 0$ as $\beta > 0$ and $V_s(c,s) \geq 0$. The CEO thus does not sabotage the successor and therefore does not become entrenched. □

Proof of Proposition 8. We know that

$$W(c,s) \leq \mathbb{E}_{c,s}\left[\int_0^{\tau_\lambda} e^{-rt} dX_t\right] = \mathbb{E}_{c,s}\left[\int_0^{\tau_\lambda} e^{-rt}\left(\mu + C_t\right) dt\right] = \frac{\mu + c}{r + \lambda}$$

as $\mathbb{E}_t\left[dX_t\right] \geq 0$, $dX_t = \left(\mu + C_t\right) dt + \frac{1}{\phi^c} dB_t^c$, and C_t is a martingale.

Given that the sample paths of S_t and C_t are continuous as long as the current CEO and successor are in place, there exists a region $\mathcal{R} \subseteq [0,1]^2$ in which the firm stays until either the CEO or successor gets replaced. Therefore, we can restrict our attention to $\mathcal{R}$.

For $(c,s) \in \mathcal{R}$, we know that $W(c,s)$ solves the differential equation

$$(r+\lambda)W(c,s) = \mu + c + \max_{f \in [0,\bar{f}]} \{-fsW_s(c,s)\} + \frac{1}{2}\left(\phi^c\right)^2 c^2 (1-c)^2 W_{cc}(c,s) + \frac{1}{2}\left(\phi^s\right)^2 s^2(1-s)^2 W_{ss}(c,s),$$

where the maximum operator follows from Equation (3) and the fact that $\alpha > 0$ and $\beta = 0$.

Since $W(c,s) \leq \frac{\mu+c}{r+\lambda}$ and $\phi^c W_{cc}(c,s) \geq 0$, we have that for $s \in (0,1)$

$$\begin{aligned}
\mu + c &\geq (r+\lambda)W(c,s) \\
&= \mu + c + \max_{f \in [0,\bar{f}]} \{-fsW_s(c,s)\} + \frac{1}{2}\left(\phi^c\right)^2 c^2(1-c)^2 W_{cc}(c,s) + \frac{1}{2}\left(\phi^s\right)^2 s^2(1-s)^2 W_{ss}(c,s) \\
&\geq \mu + c + \frac{1}{2}\left(\phi^s\right)^2 s^2(1-s)^2 W_{ss}(c,s), \\
0 &\geq W_{ss}(c,s).
\end{aligned}$$

As a consequence, $W(c,s)$ is concave in s for $(c,s) \in \mathcal{R}$ and therefore $W_s(c,s)$ can cross zero at most once and a threshold sabotaging strategy $\hat{s}(C_t|c,s)$ maximizes the CEO's compensation. □

B Numerical Procedure

This appendix describes the numerical procedure used to calculate the equity value function for the baseline model (Section I).

The equity value function $V(c, s)$ satisfies the following Hamilton-Jacobi-Bellman (HJB) equation

$$
\begin{aligned}
0 = \max \Bigg\{ & -(r+\lambda)\, V(c,s) + c + \lambda V(0,s) + \frac{1}{2}\left(\phi^c\right)^2 c^2 (1-c)^2 \frac{\partial^2 V(c,s)}{\partial^2 c} \\
& + \frac{1}{2}\left(\phi^s\right)^2 s^2 (1-s)^2 \frac{\partial^2 V(c,s)}{\partial^2 s}, V(s,0) - K - V(c,s), \\
& V(s,e) - K - \Phi - V(c,s), V(c,e) - \Phi - V(c,s), \\
& V(e,s) - K - \Phi - V(c,s), V(e,e) - K - 2\Phi - V(c,s) \Bigg\}.
\end{aligned}
$$

We try to find a solution for this HJB equation iteratively.

We first discretize the state space $(s, c) \in [0, 1]^2$. We use n equally-spaced discrete points along each dimension so our discretized state space has n^2 points: $\{s_1, ..., s_n\}$ and $\{c_1, ..., c_n\}$ with $s_1 = c_1 = 0$ and $s_n = c_n = 1$.

Start with an initial guess $V_0(c, s)$. Given $V_t(c, s)$, we then want to determine the next iteration $V_{t+\Delta_t}(c, s)$. If we keep on iterating then $\lim_{t\to\infty} V_t(c, s)$ should solve the HJB equation.

First, we loop over $c \in \{c_1, ..., c_n\}$. For each c, we solve the differential equation that is part of the HJB equation treating the term containing the second-order derivative with respect to c as given. More precisely, we use a finite difference scheme that is implicit in the s-dimension and explicit in the c-dimension with a false transient (an artificial time-derivative) (Hansen et al., 2018; Kaplan et al., 2020). Our updating equation looks as follows

$$
\begin{aligned}
V_{t+\Delta_t}(c,s) \approx V_t(c,s) + \Delta_t \Bigg\{ & -(r+\lambda)\, V_{t+\Delta_t}(c,s) + c + \lambda V_t(0,s) \\
& + \frac{1}{2}\left(\phi^c\right)^2 c^2 (1-c)^2 \frac{\partial^2 V_t(c,s)}{\partial^2 c} + \frac{1}{2}\left(\phi^s\right)^2 s^2 (1-s)^2 \frac{\partial^2 V_{t+\Delta_t}(c,s)}{\partial^2 s} \Bigg\},
\end{aligned}
$$

where Δ_t is set sufficiently small to ensure convergence.

Given the discretized state space, we can write this updating equation as

$$
\begin{aligned}
&A^c V_{t+\Delta_t}(c,:) = B_t^c, \\
&B_t^c = V_t(c,:) + \Delta_t \left(c + \lambda V_t(0,:) + \frac{1}{2} \left(\phi^c\right)^2 c^2 (1-c)^2 \frac{\partial^2 V_t(c,:)}{\partial^2 c} \right), \\
&A^c = I \left(1 + \Delta_t \left(r + \lambda\right)\right) - \Delta_t M, \\
&M_{i,i} = -\frac{\left(\phi^s\right)^2 s_i^2 (1-s_i)^2}{\Delta_s^2}, \\
&M_{i,i\pm1} = \frac{\left(\phi^s\right)^2 s_i^2 (1-s_i)^2}{2\Delta_s^2},
\end{aligned}
\tag{A.2}
$$

where I is the identity matrix and $\Delta_s = s_2 - s_1$ is the step size of the grid of s. The other elements of M are zero. We calculate the second-order derivative with respect to c using neighboring grid points

$$
\frac{\partial^2 V_t(c,s)}{\partial^2 c} = \frac{V_t(c_{j-1},s) - 2V_t(c_j,s) + V_t(c_{j+1},s)}{\Delta_c^2},
$$

where $\Delta_c = c_2 - c_1$ is the step size of the grid of c. At the boundaries of the state space, we don't need to calculate the second-order derivatives since $\frac{1}{2}\left(\phi^s\right)^2 s^2(1-s)^2 = 0$ for $s \in \{0,1\}$ and $\frac{1}{2}\left(\phi^c\right)^2 c^2(1-c)^2 = 0$ for $c \in \{0,1\}$.[27] Equation (A.2) is a system of n linear equations with n unknowns, which we can solve and has as solution $\hat{V}_{t+\Delta_t}(c,:)$.

Given this solution, we determine for every $s \in \{s_1, ..., s_n\}$ if the firm is better off changing management or delaying this change

$$
\begin{aligned}
V_{t+\Delta_t}(c,s) = \max \Big\{ &\hat{V}_{t+\Delta_t}(c,s), V_t(s,0) - K, V_t(s,e) - K - \Phi, \\
&V_t(c,e) - \Phi, V_t(e,s) - K - \Phi, V_t(e,e) - K - 2\Phi \Big\}.
\end{aligned}
$$

We repeat this procedure for every c after which we set $t = t + \Delta_t$. We keep on repeating this procedure until the average change in the equity value function,

$$
\frac{\sum_{c,s} \left|V_{t+\Delta_t}(c,s) - V_t(c,s)\right|}{n^2},
$$

is sufficiently small. The algorithm is summarized in the figure below.

[27] For the model with sabotage (Section III), we also need to calculate the first-order derivative $\frac{\partial V(c,s)}{\partial s}$. We do this by using backward differences. We don't need to calculate the derivative at the boundary $s = 0$ since $-f(c,s)sdt = 0$.

Algorithm 1: Equity Value Function

```
// Initialize
```
$V_0(c, s)$
$t = 0$
$error > value\_function\_error\_bound$

```
// Loop to update the value function
```
while *error* $>$ *value_function_error_bound* **do**

```
// Loop over CEO's expected ability
```
c
for $c \in \{c_1, ..., c_n\}$ **do**

```
// Determine updating equation
```
Calculate M
$A^c = [(1 + \Delta_t (r + \lambda)) I - \Delta_t M]$
$B_t^c = V_t(c, :) + \Delta_t \left(c + \lambda V_t(0, :) + \frac{1}{2} (\phi^c)^2 c^2(1-c)^2 \frac{\partial^2 V_t(c,:)}{\partial^2 c}\right)$

```
// Solve for
```
$\hat{V}_{t+\Delta_t}(c, :)$
Solve $A^c \hat{V}_{t+\Delta_t}(c, :) = B_t^c$

```
// Loop over successor's expected ability
```
s
for $s \in \{s_1, ..., s_n\}$ **do**

```
// Management change
```
$$V_{t+\Delta_t}(c, s) = \max \Big\{ \hat{V}_{t+\Delta_t}(c, s), V_t(s, 0) - K, V_t(s, e) - K - \Phi,$$
$$V_t(c, e) - \Phi, V_t(e, s) - K - \Phi, V_t(e, e) - K - 2\Phi \Big\}.$$

end

end

```
// Update error and time
```
$error = \frac{\sum_{c,s} |V_{t+\Delta_t}(c,s) - V_t(c,s)|}{n^2}$
$t = t + \Delta_t$

end

```
// Return results
```
return $V_t(c, s)$ and *error*