Performance as a Random Variable

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ABSTRACT

Individual performance is stochastic, but strategic human capital research evaluates workers and policies only in terms of mean or expected performance. This omission embeds strong, rarely stated assumptions about organizations' ability to absorb bad draws and capitalize on good ones. Using a portfolio model, I show that many small, poor, fragile or interdependent organizations pay a "Volatility Tax" and should prefer reliable workers at any given wage and performance level. Large, well-capitalized, or modular organizations can ignore the spread of performance and focus only on the mean. I develop this insight as Human Capital Portfolio Management and discuss implications for strategy, entrepreneurship, and organizational theory.

MANAGERIAL SUMMARY

Pick two: cheap, good, or never-has-an-off-day. Research has spent decades on the first two (wage against expected performance) but mostly treated the third as noise. I model worker consistency as a separate axis, identify three relevant human resource regimes, and highlight new areas for strategic action. The model inverts typical views on talent: strong firms can chase volatile, high-ceiling talent because they absorb the bad draws, but startups and small businesses must overpay for steadiness or court ruin.

INTRODUCTION

Organizations exist to coordinate the activities of people. And people, alongside other resources and capabilities, determine the strategy, success, and survival of the organization. The challenge, of course, is that human capital has agency (Coff, 1997). Instead of simply holding and trading (as they would a security), organizations must attract, select, hire, incentivize, promote, retain, and develop their workforce. Those that do so more effectively than their competition can achieve both near-term and sustained competitive advantage, which justifies the large and growing body of research on these activities (B. Becker & Gerhart, 1996; B. A. Campbell et al., 2012; Huselid, 1995; Lepak & Snell, 1999).

However, there is at least one important and largely neglected way that human capital behaves just like a financial asset: performance is stochastic. A worker who excels one week may struggle the next. Likewise, a newly promoted high-achiever is likely to see their performance regress towards the mean (Benson et al., 2019; Lazear, 2004). For grocery clerks (Sackett et al., 1988), school superintendents (J. C. March & March, 1977) , basketball players (Awtrey et al., 2021), executives (C. Liu & Tsay, 2021; Malmendier & Tate, 2009), and superstar scientists (L. Liu et al., 2018) alike, the difference between one person's "good" and "bad" performances can be larger than the average difference across individuals (Dalal et al., 2020).

Research has, with few exceptions, attended to only the first moment of this random variable. We study how to raise a worker's expected performance through oversight, incentives, training, and organizational design, but treat the variance as an error term or behavioral anomaly to be absorbed by the law of large numbers. In practice, workers at a given level of productivity will vary in their performance from period to period. Studies suggest that a worker's propensity to underperform or overachieve against expectations is a feature of the person-role combination and only loosely correlated with skill-level or expected output (Beus & Whitman, 2012; Dalal et al., 2009; Fleeson &

Jayawickreme, 2015; J. C. March & March, 1977; R. E. Ployhart & Hakel, 1998). In other words, there is an entire dimension of worker performance which is silently assumed away by most human capital strategy work.

Inasmuch as bad days for the person can translate to bad days for the organization, worker volatility presents a material human capital management challenge on par with worker mobility, bargaining, and motivation (Coff, 1997). But how much does it matter for strategy? Certainly, not all organizations are equally exposed. The instinct to simply hire, promote, or retain the "best" worker is likely to be right more often than not. Conversely, we can just as easily imagine a level of volatility or uncertainty in output that would make a manager pine for someone steady, boring, and reliably mediocre.

Human capital strategy needs a set of scope conditions with regard to worker volatility. I approach this problem with a formal model of worker retention in which a decision-maker chooses to retain a reliable worker or replace them with a more volatile, uncertain candidate. I calculate the organization's specific preference for reliability or exposure to volatility as a function of resources, scale, workforce composition, and production function. The model takes inspiration from asset pricing models and extends readily to other human capital management choices.

Consistent with our understanding of other risky resources or assets, the model suggests that not all organizations are equally exposed. Large, wealthy, and durable organizations can largely ignore individual-scale negative shocks while still capitalizing on positive events. Small, poor, or fragile entities, on the other hand, cannot self-insure against worker volatility and so must pay higher wages, accept lower expected performance, or sacrifice competitive fitness. In other words, rich companies can pay for high average performance. Poor companies must pay for reliability as well. I label this gap between have and have-nots the "Volatility Tax" and show that it neatly divides human capital management into three different regimes with respect to worker volatility. I then extend these findings to more complex and interconnected production environments.

This paper is the first to treat persistent, within-person performance spread as a strategic dimension of human capital. Beyond their value in setting scope conditions for HR/HCM research, these findings have implications for entrepreneurship and the design and management of organizations. I organize these into a research program called Human Capital Portfolio Management (HCPM) and argue that organizations should develop capabilities in three areas: measurement of worker volatility; management of individual volatility with familiar HR interventions; and the design and management of workforce portfolios. Importantly, the implications of Human Capital Portfolio Management are distinct from those found in the study of other risk-return tradeoffs because worker volatility arises from fundamentally different sources and because organizations are uniquely constrained in their interpretation, measurement, and management. HCPM is also an inherently microfounded approach (Felin & Foss, 2005; T. Ployhart, 2011; Puranam, 2018) that can be connected to the literatures on resources/capabilities (Barney, 1991; B. A. Campbell et al., 2012; Coff, 1997; R. E. Ployhart et al., 2014; Sirmon et al., 2007; Teece et al., 1997) and strategy setting (Denrell, 2005; Denrell & Liu, 2012; J. G. March, 1991).

A PRACTICAL EXAMPLE

Consider a stylized managerial dilemma. Worker A is known for their consistency. They come to work every day but never work overtime. They always produce acceptable work, but never anything exceptional. One day, Worker A requests a substantial raise and informs their manager that they will leave the organization unless they receive it.

The manager is confident that Worker A's requested salary would also be sufficient to attract Candidate B. After extensive reference checks, aptitude tests, and structured interviews, the manager is convinced that Candidate B can be expected to produce far more than Worker A in the same role. The choice is obvious, right? For the same wages, the manager would be foolish not to replace the pedestrian Worker A with the exceptional

Candidate B.

But what if Candidate B's performance is stochastic, drawing from a distribution of possible outcomes? If the role is a creative one, we might frame this as Candidate B mixing great ideas with bad ideas or punctuating a series of very bad designs with moments of brilliance. In a throughput-oriented role like sales, we might think of them as exceeding their quota in some periods while delivering almost nothing in others. Meanwhile, Worker A's performance is unvarying.[1]

With this modification, the choice is no longer obvious. In some periods, Candidate B will underperform Worker A. Depending on the shape of their performance distribution, Candidate B may be a net-negative for the organization for extended periods of time. Candidate B may also produce a volume of work, in a single period, that the organization is unable to absorb. If there are other upstream or downstream functions that depend on this role, they may be unwillingly pulled into Candidate B's ebbs and flows, even if they themselves are otherwise reliable in their output.

Additionally, Worker A's performance has been observed, by their manager, over a span of years and so is comparatively better understood. Candidate B performed brilliantly in the interview process, but that represents only a handful of observations. It's possible that Candidate B is highly reliable and much better than Worker A. It is also possible that they simply had a really "good day" at just the right time to advance their career. Perhaps their focus and motivation were at high-water marks due to their desire for the new role.

Preferring Candidate B now requires the manager to hold three additional beliefs:

1. Candidate B's interview performance is representative of their mean task performance should they be hired.

[1] One important aside: It can be tempting to impose stereotypes and preferences on both workers: Worker A's performance is boring so they must be an unambitious individual who values consistency and abhors risk; Candidate B is a bit wild, so they must be difficult to manage or more open to variable compensation. This is understandable, but incorrect. Personality differences can impact performance spread, but they are not the same thing. Candidate B could be risk-averse, precisely because they already experience their own boom-and-bust cycles. Or perhaps Worker A's penchant for risky personal decisions disciplines their work habits. Without clear evidence in either direction, I argue, organizations should manage volatility directly.

2. The organization can weather periods in which Candidate B produces less than Worker A (or nothing at all).

3. Candidate B's output will arrive at a cadence which the organization can convert into value and which does not generate expensive or unsurvivable volatility elsewhere in the organization.

If any of these assumptions do not hold, the organization may (correctly) pass on the exceptional talent and instead pay a premium to retain someone that, by its own estimation, is less talented and productive. The model that follows builds on this example. I focus on retention (and hold mean performance constant) for simplicity, but the implications of the model apply similarly to hiring, benefits, compensation, management, organizational structure, role definition, and other aspects of HCM. We could easily reformat this example for a promotion decision or an internal labor market where information about both candidates is known.

MODEL OVERVIEW

I use a standard definition of worker performance as the aggregated value to the organization of discrete episodes of worker activity (Motowidlo et al., 1997). Each individual performs a set of activities at a point in time in an effort to complete a task. The effectiveness of those behaviors is conditioned by a set of state variables that include resources, firm-specific features, institutions, and the environment. This leaves performance on any given task as a function of the individual's capabilities, their fit with the demands of the task, and their mood, motivation, affect, and attention at the time of the task. And unlike learning curves or age-related maturation trajectories (Bavafa & Jónasson, 2021), volatility is non-directional and typically mean-reverting, suggesting that performance fluctuates above and below a stable personal baseline.

Workers can be low-mean or high-mean and low-volatility or high-volatility and

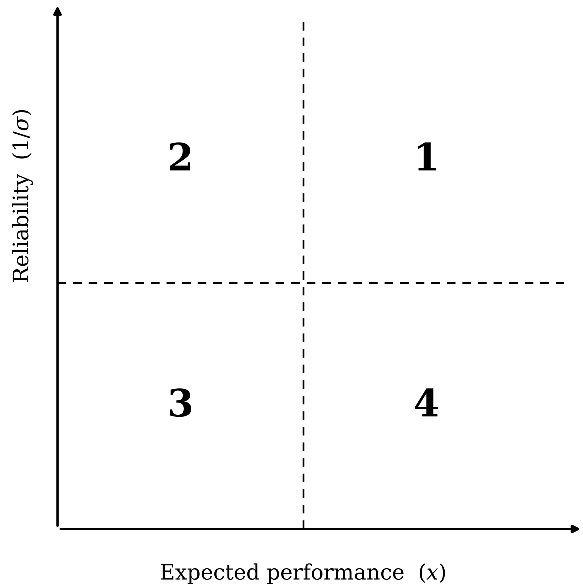

Figure 1: Two dimensions of worker performance

though these are continuous measures, we can develop useful intuition from simple categories. Figure 1 sorts workers into four categories. Quadrant 1 includes workers that are high mean, high reliability. These are superstars and the kind of worker that every organization should hire, retain, and support. Quadrant 3 is the reverse: low-performing, unpredictable, and rarely worth keeping onboard. The remaining two quadrants, which correspond to Worker A and Candidate B from the earlier worked example, present a tradeoff. Is it optimal to hire workers that are great, on average, but have moments of very poor performance? Or would an organization benefit from workers that are not very "good" but provide a stable period-to-period foundation? This tradeoff is also fractal. Within any given quadrant, there should still be gradients of quality and reliability. So even wealthy organizations with the resources to hire "the best" can still benefit from distinguishing between reliable and performant candidates.

In practice, the choice of candidate or quadrant depends on the specifics of the organization, workers, and the labor market. Each team, firm, or manager has a unique set of isoquants which reflect relative value of each type of worker at a given wage. The model below sidesteps this complexity by setting mean performance and wages equal between two worker types and pricing only the difference in volatility or uncertainty. In effect, this compares Quadrant 1 with Quadrant 4 (high mean workers with differing reliability) and, equivalently, Quadrant 2 against Quadrant 3.

Hereafter, I use the terms performance, productivity, and output interchangeably to denote a worker's contribution to the organization's production function. This is a minor abuse of terminology (elsewhere, performance is used to denote behaviors and productivity the resulting value as in J. P. Campbell and Wiernik, 2015) which I justify by noting that the firm's strategy does not distinguish between the two. The conversion of behaviors into value is an operational challenge, but the choice of employees and the composition of a firm's human capital portfolio is strategic.

Two Workers

I model an organization's choice between two workers. The first type is Reliable while the second is Volatile. As in the prior example, I will assume that the Reliable worker is currently employed and that the decision-maker has full information about their type. Each Reliable-type worker produces deterministic and positive productivity for the organization each period: $x_r > 0$. A Volatile-type worker's performance is stochastic with mean and standard deviation: $x_v \sim (x_r, \sigma)$. Rather than specify a distribution (and to avoid wading into an ongoing debate[2]), I model volatile performance as a location-scale transform of a fixed, mean-zero shock:

$$x_v = x_r + \sigma z, \qquad E[z] = 0, \qquad \mathrm{Var}(z) = 1,$$

where z is continuous, has a single-peaked density, and has finite moments. σ is the volatile worker's standard deviation. Because $E[x_v] = x_r$, the two workers share an expected

[2] See O'Boyle Jr. and Aguinis (2012), Beck et al. (2014), Spain et al. (2013), and Bradley and Aguinis (2023), among many others.

output and the volatile worker is a mean-preserving spread (Rothschild & Stiglitz, 1970), raising σ moves mass into both tails while holding the mean fixed. Some of the results that follow use one additional regularity condition. Under additive production, the two firms' output distributions (retained and replacement) cross once in each tail. The lower-variance retained state has greater density near the common mean, while the volatile replacement state has greater density in the tails.

The worker's mean and standard deviation (x_r and σ) reflect the manager's beliefs about each worker's future performance in their assigned role. The true parameters of the underlying performance distribution are unknowable. For the retained worker, these beliefs are informed by an extended track record and are comparatively precise. For the replacement candidate, beliefs are formed from a limited set of signals and so carry greater uncertainty. Though I label the replacement candidate as a Volatile type, the model doesn't distinguish between sources of uncertainty. In the mind of the manager, there is no difference between a truly volatile candidate whose performance distribution is correctly estimated and one whose performance is stable but poorly estimated. Both uncertainties fold into σ and the model results can be interpreted in light of either interpretation. An organization that cannot absorb a volatile employee also cannot absorb the uncertainty inherent in hiring a new worker, even if the latter seems to be reliable.

However, for purposes of firm strategy, it is the former interpretation of uncertainty and volatility that I focus on here. There is a substantial body of research addressed to the problem of labor market signaling uncertainty (Altonji & Pierret, 2001; Jovanovic, 1979; Spence, 1973), but it generally assumes that time and repeated observation reduce noise. A "wait-and-see" approach will have no effect on the kind of enduring, work/role-specific volatility addressed here. If anything, the model below suggests a firm that naively assumes that every worker will eventually "settle down" is likely to operate at a disadvantage against its more sophisticated peers.

The Organization

A representative organization has a workforce consisting of these two worker types (N^r, N^v with some x_r and σ) and a production process $Q(N^r, N^v)$ which converts individual worker output into the organization's output. The organization also has some resource position in each period (W_t), net of prior period profits, shocks, and ordinary frictions of business. Resources include the organization's capital, assets, capabilities, reputation, and credit-worthiness (Barney, 1991). Profits carry forward: $W_{t+1} = W_t + Q(N^r, N^v)$. Prices are normalized to one, wages are included in productivity, and all other costs are normalized to zero.

I assume that worker performance variation is independent of other workers and of the firm's resource position. In practice, firm-level conditions can introduce a correlated performance risk which amplifies output variance substantially. If workers' bad days are likely to overlap, the effective volatility of the portfolio is even higher than the model assumes and the reliability premium is larger (so long as the organization is not otherwise insured against left-tail risk). If, as is likely, there is some measure of covariance in worker performance, then the below results represent a conservative lower bound on the importance of performance volatility to strategy.

Baseline features of the model can be interpreted as indications of the quality of the organization or environment. All entities have the same risk tolerance and decision-making quality, but highly productive employees (high x_r) suggest a more effective organization, a more favorable environment, or a better business theory. Likewise, greater wealth (W_t) can be interpreted as an indicator of the quality of the organization or its aptitude with regard to raising capital or attracting talent.

Production Functions

The impact of one person's volatility on the organization depends on how their productivity translates into organization output. If an employee is a single point of failure for an entire factory, the impact of any error or left-tail draw is magnified. An employee working independently is more limited in the damage that they can do, but the organization still cannot derive outsized benefits from over-performance. Because the way that worker performance combines is, itself, a property of the role and task (T. Ployhart, 2011), I model three production functions, each chosen to illustrate one extreme of independence and inter-connectivity.

Additive production, in which all employees work independently and are perfect substitutes:

$$Q(N^r, N^v) = N^r x_r + \sum_{n=1}^{N^v} x_{v,n}$$

This is a reasonable representation of many small companies as well as some teams. Consider, as examples, a sales organization in which productivity is the sum of the individual agents' sales or a piecework manufacturing facility where output is the sum of the individual workers' productivity. Organizations or teams with additive production are equally sensitive to left and right-tail variance.

Leontief production, in which all workers are interdependent:

$$Q(N^r, N^v) = A(N) \cdot min(x_r, x_{v,1} ... x_{v,n})$$

The throughput of the system is equal to the lowest performing individual or station, then scaled by some positive, strictly increasing, unbounded function $A(N)$ such that $A(N+1) > A(N)$ and $A(N) \to \infty$.

Beyond the obvious applications to assembly-line manufacturing, many small companies also, effectively, operate on this kind of production. Consider a firm with three employees: an engineer, a sales agent, and a consultant/delivery expert. To generate revenue, the engineer must produce a product, the sales agent must sell it, and the consultant must implement it. A bad performance from any one person nullifies the entire organization's output (Kremer, 1993; Perrow, 1984).

The Leontief is the most sensitive to left-tail variance and is unable to extract any value from right-tail variance. It is the opposite of additive production in that workers are perfectly interdependent. In practice, most organizations fall somewhere between these two. For example, organizational decoupling (Orton & Weick, 1990; Weick, 1976), and slack in intra-organization handoffs effectively provide a buffer against events or shocks by allowing two functions to be nominally interdependent but practically disconnected and temporally independent (Bourgeois, 1981; Cyert & March, 1963; Meyer & Rowan, 1977). Likewise, resource redeployability and organizational ambidexterity reduce the costs of production slowdowns elsewhere in the organization (Helfat & Eisenhardt, 2004; O'Reilly & Tushman, 2013; Sakhartov & Folta, 2014).

The effectiveness of these interventions determines where, on the Additive-Leontief continuum an organization falls and how much weight each of the model's respective predictions should receive. Organizations with tightly coupled production or no tolerance for failure should attend primarily to the Leontief results. Those with modular structures will find more value in the additive case. Note that I do not model these intermediate functions directly. This is done for analytical tractability and because these chosen extremes effectively bound a larger space of different production functions. Choosing an interior production function (Cobb-Douglas, for example) yields combinations of these behaviors with ambiguous magnitudes and conflicting signs. As the objective of this project is simply to derive scope conditions, this adds complexity without correspondingly useful insight.

Competitive or Tournament production in which only the best performance within a team or organization matters:

$$Q(N^r, N^v) = A(N) \cdot max(x_r, x_{v,1}...x_{v,n})$$

Within an organization, functions and teams may have different levels of interdependence, with different production functions at the business unit or organizational level. It is difficult to imagine an entire organization with competitive production, but many individual functions will follow this kind of "sweepstakes" in which the best idea or concept is employed elsewhere in the organization (Boudreau et al., 2011; Dahan & Mendelson, 2001). Consider a lab in which a team of inventors each produce their own prototype: the organization selects the best of the prototypes and puts it into production and the second best idea is scrapped. Competitive production is largely immune to left tail variance (so long as the organization has a single Reliable-type employee, as I will discuss), and benefits fully from right-tail variance.

Competitive production also helps address a category of production in which two or more complementary inputs generate outsized value when paired together (Athey & Stern, 1998). These cooperative or synergistic production functions lie on a continuum between competitive and additive production and share a relative immunity to left-tail variance and ability to capture right-tail variance.

Terminal Failure

Should the organization exhaust its resources, it fails and receives no profits in the future.[3] In exchange for taking on marginal failure risk by hiring a volatile worker, the manager requires compensation commensurate with the risk. Because organization size, composition, and features interact to make the organization more durable or fragile, the preference for workers of a certain type varies over time and across settings.

The idea that risk-of-failure warps decision-making and creates a preference for volatility is well-understood in other literatures. Real-options theory shows that volatility increases the value of assets with capped downside (McGrath, 1999). Decision-makers with little to lose take larger risks (Kahneman & Tversky, 1979; J. G. March & Shapira, 1987). Lagging firms invest more heavily (and riskily) in R&D (Cabral, 2003). Fund managers

[3] This is a standard feature of ecological or chance models in strategy (Denrell, 2004, 2005; Denrell & Liu, 2012; Levinthal, 1991; J. G. March, 1991).

with underwhelming returns take more uncertain bets (Agarwal et al., 2011; Brown et al., 1996). And an extensive body of lab studies suggests that the absence of risk, either because failure is certain or because the agent is playing with house money, leads to a preference for high-upside plays (Thaler & Johnson, 1990). This paper extends that same logic to workforce composition by allowing first period wealth to be negative. The second period, then, becomes the organization's last-chance to survive.

Hereafter, I refer to this state of exhaustion as "failure" though it need not only represent cases where an organization ceases to function. Instead, this is designed to capture any disproportionately negative outcome for the decision-maker. The failure state embeds two additional assumptions about the organization. First, the consequences of failure (manager termination, firm insolvency, investor displeasure, margin calls, etc.) must apply directly to the decision-making entity. By construction, there is no principal-agent risk (Jensen & Meckling, 1976) in the model. However, where the decision-maker internalizes only a fraction of the organization's failure penalty, their preference for volatility may be suboptimal for the organization (Coles et al., 2006; Gompers & Lerner, 1999). This is not modeled explicitly but I instead flag it as a caveat to the model results.

Second, left-tail risk and consequences must resolve at a relevant frequency. If worker output is highly volatile at the daily level, but the organization only realizes the consequences when payroll runs every month, then the law of large numbers makes it likely that a bad day will be balanced out before it harms the organization. On the other hand, a sales representative or team with volatile annual performance can cause a promising organization to fail with a sufficiently bad week at year-end. A deal that closes on January 1st is worth substantially less to both the organization and the worker than an otherwise identical sale which is signed at 11:59 pm on December 31st.

The flow of the model is such that the organization hires a single worker, then all workers work, and the organization realizes profits or losses. A company may hire a third worker months or years after their second, but employees 99 and 100 might start on the same day. For convenience, I do not specify the length of a period, but the model assumes that the performance and profit intervals are identical and non-negligible (Samuelson, 1963). Performance on any time scale can function as an aggregation of many smaller-scale draws, so x_v is the convolution of however many individual draws the worker may make in the same period as the organization realizes its performance. Still, to avoid unsupportable claims, I make no magnitude comparisons across different parameter sets and instead build theory off of comparative statics.

The Manager's Problem

This model differs from Markowitz (1952), March (1991), and other antecedents in its emphasis on a single retention/hiring choice. Portfolio management and exploration-exploitation models optimize the allocation of resources across a set of alternatives and allow for a complete rebalancing of investments in each period. In finance, this is entirely appropriate. An investor whose risk tolerance or liquidity needs change can sell or trade assets in response. However, investments in existing products and/or new product development entail discrete commitments to both workers and fixed assets, and so are more difficult to unwind. A manager cannot costlessly reshuffle their entire headcount spend to new workers. [4]

The state at time t is defined by the organization's wealth and the number of each employee type that it currently employs: (W_t, N^r, N^v). Resources and profits carry forward according to: $W_{t+1} = W_t + Q(N^r, N^v)$ and the organization fails and liquidates if $W_{t+1} < 0$. The probability of survival is $S(W_t, N^r, N^v) = Pr(W_{t+1} \geq 0 | W_t, N^r, N^v)$.

I collapse all future period payoffs into a positive, bounded continuation value $V(N)$, which represents the value of the organization's workforce conditional on survival. This value captures organization-specific planning horizons and discounting.

[4] To be clear, this is not a criticism of March (1991); his work is concerned first with the firm's posture towards learning and is given proper microfoundations and frictions by Siggelkow and Levinthal (2003) among others. Rather, I note the distinction because human capital is uniquely difficult to re-balance in this way (Coff, 1997).

The manager chooses whether to retain the reliable worker or replace them with a volatile worker with the ultimate objective of maximizing total returns:

$$\begin{aligned} max\{ & \underbrace{E[Q(N^r, N^v)] + S(W_t, N^r, N^v)V(N)}_{\text{retain reliable worker}} \\ & \underbrace{E[Q(N^r - 1, N^v + 1)] + S(W_t, N^r - 1, N^v + 1)V(N)}_{\text{replace with volatile worker}}\} \end{aligned} \tag{1}$$

The two worker types differ only in the spread of their performance and the resulting impact on survival:
$V(N^r, N^v) = V(N^r - 1, N^v + 1)$ and $S(W_t, N^r, N^v) \neq S(W_t, N^r - 1, N^v + 1)$. To capture this difference, I introduce the Reliability Premium (λ) which is paid out in the initial period. This compensating differential reflects the relative value of a reliable worker compared to a volatile worker in a given state. Formally:

$$\begin{aligned} \lambda = & \underbrace{[S(W_t, N^r, N^v) - S(W_t, N^r - 1, N^v + 1)]}_{\text{difference in survival rates}} \times \underbrace{V(N)}_{\text{continuation value}} \\ & + \underbrace{E[Q(N^r, N^v)] - E[Q(N^r - 1, N^v + 1)]}_{D \text{ (difference in expected output)}} \end{aligned} \tag{2}$$

The first term prices the marginal failure risk the volatile worker introduces. The second, D, is the difference in expected organizational output between the two choices. Because the two worker types share a common mean, D vanishes under additive production. Under interdependent or competitive production the firm's output is nonlinear in worker output, so D takes a definite sign:

$$D \equiv E[Q(N^r, N^v)] - E[Q(N^r - 1, N^v + 1)],$$

$$D \begin{cases} = 0 & \text{additive production (sum)} \\ \geq 0 & \text{Leontief production (min)} \\ \leq 0 & \text{competitive production (max)} \end{cases} \tag{3}$$

Table 1: Model parameters and notation

Symbol	Meaning
N^r	Number of reliable-type workers
N^v	Number of volatile-type workers
N	Total workforce: $N^r + N^v$
x_r	Reliable worker's per-period productivity ($x_r > 0$); also volatile worker's mean (by construction)
x_v	Volatile worker's stochastic performance, $x_v \sim (x_r, \sigma)$
σ	Std. dev. of volatile performance (volatility); also absorbs estimation uncertainty
$Q(N^r, N^v)$	Production function (additive / Leontief / competitive)
$A(N)$	Scale function in Leontief and competitive production
W_t	Resource position (wealth) at time t
W_{t+1}	Next-period wealth; $W_{t+1} = W_t + Q(N^r, N^v)$
$S(W_t, N^r, N^v)$	Survival probability $= Pr(W_{t+1} \geq 0 \mid W_t, N^r, N^v)$
$V(N)$	Continuation value
λ	Reliability premium (compensating differential)
D	Difference in expected output between worker types
t	Period index

Reliability Premium, Volatility Tax

The manager prefers the volatile candidate if the difference in their performance or compensation compared to a reliable employee is, in expectation, greater than the marginal risk of failure multiplied by expected productivity in future periods. This premium could be denominated in wages or indicative of differences in mean performance. It might also represent the value of information about a worker's type.

By construction, there is no reliability premium when the hiring manager's choice has no impact on survival. If failure is certain, survival is guaranteed, or some other feature of the organization provides insurance against worker volatility ($S(W_t, N^r, N^v) = S(W_t, N^r - 1, N^v + 1)$), λ will be equal to zero or D and the hiring manager will be free to choose the "best" candidate by expected performance.

Organizations would doubtless prefer to have a lower reliability premium, but there will naturally be differences in premiums across entities or firms. This gap, which I label the "Volatility Tax," represents the disadvantage incurred by organizations that are sensitive to volatility.

Finally, recall that the primary objective of this paper is to determine which organizations are exposed to performance volatility risk. The reliability premium on a marginal worker is sufficient to gauge the direction and magnitude of this risk. A thoughtful reader may immediately jump to portfolio-like organizational implications (hiring, redeployment, ambidexterity, etc.) à la Markowitz or March, but this is outside the scope of this model and reserved for the discussion. Below, I first develop the model using additive production. I then show how findings from this base case evolve in response to more interconnected or competitive production functions.

RESULTS FROM ADDITIVE PRODUCTION

To build intuition, it is helpful to look at the model through the lens of basic probability. As structured, an organization's wealth in the next period is the current wealth plus the sum of this period's worker performance draws. With independent workers, that sum is a convolution, and so organizational output is itself a distribution. The manager's whole problem thus reduces to a simple question of how to reduce probability mass on the wrong side of zero. The manager would prefer to hire the highest-mean worker, regardless of the distribution of performance. However, a more volatile worker fattens the left tail of the organizational distribution. The increased failure risk is priced by the reliability premium.

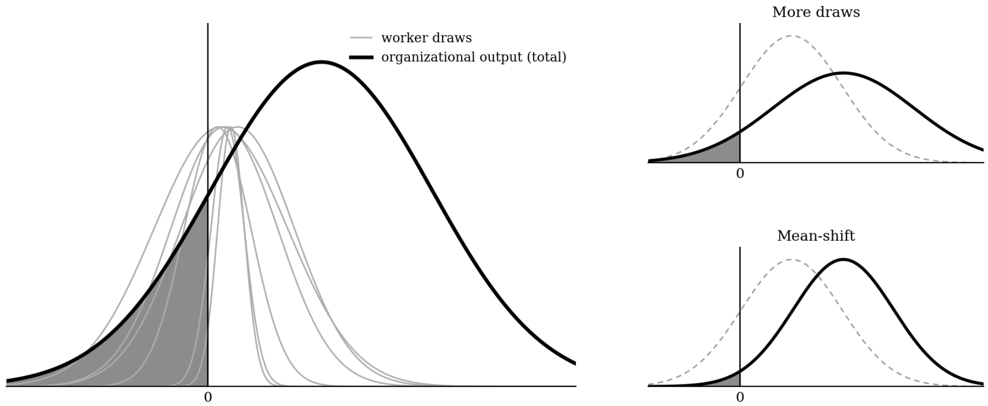

Figure 2: Left Panel - Under additive production, organizational performance is the convolution of worker performance draws.
Right Panel - Organizations can reduce risk associated with stochastic worker performance by adding more draws or by mean-shifting the organization relative to the failure point.

The manager has two levers to reduce the probability of failure, as shown in Figure 2. First, more draws from more workers pull mass from the tails of the organization's distribution to the center via the law of large numbers. Alternately, an increase in wealth or worker productivity shifts the entire distribution to the right, reducing the likelihood that any one worker's bad day can be catastrophic for the organization as a whole.

Wealth and Scale

The reliable worker is risk-free with positive performance. The survival rate $S(\cdot)$ is increasing in W_t and N^r. Given that volatility is uncorrelated across workers, additive production also produces an asymptotically increasing survival rate in N^v, though it grows more slowly than N^r. Continuation value $V(\cdot)$ is monotonically increasing in N.

It follows that increases in the number of employees reduce the reliability premium by increasing the chance of survival. When the organization is sufficiently large, the probability of survival is independent of the choice and so the reliability premium goes to zero, leaving the organization indifferent between worker types on the basis of volatility. Matching the intuition from Figure 2, this is the scale effect:

Proposition 1 (Scale effect)**.** *Under additive production, while*

$S(W_t, N^r, N^v) > S(W_t, N^r - 1, N^v + 1)$, *the reliability premium is positive and vanishes as the workforce grows large:*

$$\lambda > 0, \qquad \lim_{N^r + N^v \to \infty} \lambda = 0.$$

The same mechanics and intuition apply to resources and wealth. Under additive production, an organization possessing a large stock of valuable resources cannot fail as a result of individual, non-systemic volatility. Let W_A^* denote the wealth level corresponding to the lower-tail density crossing in the output distributions. Beyond W_A^*, the reliability premium is decreasing in resources until the organization accumulates sufficient wealth to ignore volatility altogether. Model features which shift output relative to the failure threshold behave similarly under mild assumptions. This is the wealth effect:

Proposition 2 (Wealth effect)**.** *Under additive production, while* $W_t > W_A^*$*, the reliability premium is positive and decreasing in resources, and goes to zero as they grow large:*

$$\lambda > 0, \qquad \frac{\partial \lambda}{\partial W_t} < 0, \qquad \lim_{W_t \to \infty} \lambda = 0.$$

Volatility as Liability of Smallness

The Volatility Tax has three interpretations. It can represent the gap between sophisticated organizations (those with an understanding of performance as a random variable and the ability to measure it) and naive hiring managers (those who attend only to expected performance). If all parties are aware of a worker's penchant for bad days, the Volatility Tax represents the value of correct information about the spread of a worker's performance. However, most notably, in an environment with full information and sophisticated hiring practices, the Volatility Tax is a structural penalty imposed only on small, poor, and fragile organizations (Propositions 1 and 2).[5] Calling back to the initial example, a higher volatility tax means that the firm is less able to weather periods in which

[5]The appendix provides a worked numerical example.

a worker produces nothing of value. These are the organizations that should, rationally, choose the unremarkable employee over the superstar, and they are worse for it.

Resource and capability constraints represent a well-documented hazard (Stinchcombe, 1965). Organizations lacking cash reserves, human capital, credit, or reputation are less able to weather shocks, respond quickly to opportunities, or make larger and more efficient investments. The Volatility Tax can be added to these "liabilities of smallness" because it presents resource-constrained organizations with a dilemma in which every alternative carries with it some cost that can only be defrayed by growing large or wealthy. Hire the best employees but risk failure due to one bad day? Retain mediocre workers? Overpay for workers who are neither mediocre nor volatile? Or make costly investments to redesign internal processes and structures? There is no right answer, but organizations that fail to navigate this choice space effectively are likely to disappear.

As a general rule, the liabilities of smallness exert a pull which only organizations that are sufficiently lucky and capable can escape. Those that make it out of the gravity well do so by expanding their resources and capabilities. As a result, the antecedents, mechanisms, and impacts of growth are central to entrepreneurial strategy (DeSantola & Gulati, 2017). The volatility tax represents a novel contribution to this literature, though it also complicates our understanding of growth strategy.

Conventional wisdom suggests that entrepreneurs need to take large risks in order to succeed. Some of this is definitional: every founder wagers that their business can create value that is either overlooked or inaccessible to better-resourced organizations. More materially, scale conveys a compounding advantage. Organizations in a lagging position need to take risks in order to avert a vicious cycle in which the rich get richer and the small and nascent inevitably close up shop (Aghion et al., 2001; Cabral & Mata, 2003; Denrell, 2005; J. G. March, 1991). But startups that play high-variance human capital strategies, are likely to incur the volatility tax, further diminishing the likelihood of success. Worker volatility compounds preexisting challenges in HCM and so is akin to the tyranny of the

Tsiolkovsky rocket equation in which the weight of fuel needed to proceed to space requires exponentially more fuel to lift it to the point where it can be burnt. However, this also suggests that better management of volatility is one path to more effective entrepreneurial strategy.

Wealth as Treatment

Just as gravity wanes with distance, so too do the liabilities of smallness and poorness. When an organization reaches sufficient scale, volatility ceases to be a problem. Compared to smaller organizations, larger organizations can either employ better workers for the same wages or the same workers at a discount. This is consistent with our understanding of assortative matching, which suggests that workers and organizations mutually sort and match with similar quality counterparts (Kremer, 1993). There are a variety of mechanisms, but assortative matching is typically framed as a function of a richer organization being able to pay better wages, make complementary investments, or otherwise become more attractive to candidates by *using* its resources (Abowd et al., 1999; G. S. Becker, 1973; Ouimet & Zarutskie, 2014). Uniquely, in this model, the organization does not pay a premium for talent. Rather, because it has a lower reliability premium, it is more able to absorb and retain talent that is high mean but high volatility. So long as there is sufficient dry powder (in the form of capital, credit, scale, or reputation) to weather small-scale, uncorrelated shocks, the wealthy organization gets better talent without paying for it.

In this, heterogeneous worker performance risk exposure functions like reputation with regard to human capital management. Highly regarded organizations can attract and retain top talent without paying a commensurate premium (Burbano, 2016; Sorkin, 2018) which, in turn, creates a self-reinforcing cycle of sustained competitive advantage.

This also bears directly on our understanding of the role of venture capital in firm success. While there is strong evidence that venture capital helps firms grow (Davila et al., 2003; Hellmann & Puri, 2002; Kortum & Lerner, 2000; Puri & Zarutskie, 2012), it is sometimes difficult to separate treatment and selection effects (Nanda & Rhodes-Kropf, 2013; Sørensen, 2007; Sorenson & Stuart, 2001). Consistent with evidence that wealth alone can produce better outcomes (McKenzie, 2017), this model suggests that added investment benefits the receiving organization by allowing it to ignore the volatility tax and instead employ better employees than less well-funded competitors.

The implication is that access to capital is even more important for small organizations and that the specific use of funds is important. Whereas venture capitalists or aggressive leaders may strive to be on the frontier of growth, an organization with enough unspent funds to insure against worker volatility (Puri & Zarutskie, 2012) can employ better workers than otherwise. This partially offsets the opportunity cost of running lean and allows these capital reserves to remain as a store of organizational slack and a hedge against other types of risk (so long as these risks are uncorrelated with worker volatility). Unspent funds thus convey some of the benefits of scale without imposing any compensating liabilities.

Many investors contribute not just their capital but also their imprimatur. Taking the broader definition of resources, this suggests that small and new businesses might benefit as much from the implied backstop of a committed investor as they do from the capital itself (Stuart et al., 1999). And because the reserves of a high-profile venture capital fund are functionally unlimited compared to those of a startup, a growth-oriented founder can spend every penny of liquid capital on capable and volatile talent, effectively borrowing against their funders' reputations to hire "better" employees than would otherwise be optimal.

The reverse of this wealth effect suggests that the optimal growth path for a small organization is more conservative than conventional wisdom suggests (Aldrich & Ruef, 2018). No matter how compelling the business idea, an organization with neither cash reserves nor noteworthy investors should be careful to avoid following in the footsteps of its unicorn forebears and gazelle peers.

The Failing Venture

But if the Volatility Tax incentivizes small organizations to hire reliable workers (Propositions 1 and 2) , why does it *feel* like the opposite is true? We might associate larger organizations with more conservative workers and startups with colorful and eccentric personalities. The staid, Swingline stapler-loving accountant simply doesn't work at a startup and the brilliant ayahuasca enthusiast has no time for the bureaucracy and formality of an established firm.

While no empirical work has examined the volatility of startup workers, there is strong evidence that early hires in small firms are younger, less-skilled, less-educated, and more likely to have been previously unemployed (Coad et al., 2014, 2017; Dahl & Klepper, 2015). How do we square the implications of Proposition 1 with evidence that startups are not hiring purely for expected performance (by most conventional metrics)?

In the model, an organization in a sufficiently precarious position (low wealth, low quality, volatile market, etc.), has negligible marginal failure probability associated with a volatile worker. As organizations receive a payout of zero when they fail (and the entrepreneur/manager can collect on their outside option), there is, effectively, downside protection at high failure rates. A Reliable-type employee has limited value because the organization will likely fail with or without them. A Volatile-type employee's left-tail variance has little downside because the marginal probability of failure is small but the right-tail of the Volatile-type employee offers potential returns and a stay of execution.

In these cases the reliability premium is non-positive. A volatile replacement of equal mean raises the chance of an above-threshold draw and so lowers the premium. With no volatile worker on hand ($N^v = 0$) the premium declines in volatility. With one already in place ($N^v \geq 1$) its marginal response to volatility is negative at $\sigma \to 0^+$.

Proposition 3 (Imminent Failure)**.** *Under additive production, when*

$S(W_t, N^r, N^v) < S(W_t, N^r - 1, N^v + 1)$*, the reliability premium is non-positive, and its marginal response to volatility is negative as* $\sigma \to 0^+$*:*

$$\lambda \leq 0, \qquad \left.\frac{\partial \lambda}{\partial \sigma}\right|_{\sigma \to 0^+} < 0.$$

For $N^v = 0$ *the retained firm is deterministic and* $\partial\lambda/\partial\sigma < 0$ *for all* σ*.*

So how common is this category of strategies? Such risk-taking behavior is commonly observed in both management and investment decisions and is consistent with the behavioral theory of the firm (Cyert & March, 1963). Organizations with strong prior performance take fewer risks. Those in dire straits take more risks and consequently perform worse, even after conditioning on resources/wealth (Bromiley, 1991; Eisdorfer, 2008; Leland, 1998). Hedge funds take riskier bets as they near the end of a reporting period in which present performance is poor and mutual fund managers whose returns lag behind competitors or peers increase fund volatility in the hopes of resurrecting their performance ranking (Brown et al., 1996). Precarious startups behave similarly (Angus, 2019; Ref et al., 2024).

This model requires that the focal organization be at risk of imminent failure before this kind of risky HCM is optimal, but with minimal loss, we can allow only that the decision-maker believes that they are at risk of failure. The real failure rate for an organization is unknowable, so a boundedly rational manager may conclude that they should hire volatile workers when the opposite is true. The reverse is also possible, though excessively employing reliable workers is unlikely to be a terminal mistake. In either case, optimal worker selection (and, therefore, growth) depends on being able to accurately gauge the quality of a theory of business, which is no small task (Felin & Zenger, 2009).

And for many founders, the belief that failure is always close by may not be entirely wrong. The overwhelming majority of startups will fail (Fairlie et al., 2023), but not before experiencing a brief indemnification from performance volatility risk. In any population, some number of these organizations will survive thanks to a favorable draw from a less-than-reliable employee. The unexpected stroke of genius can become a part of an organization's mythology, which, when paired with survivorship bias, would account for the salience of oddballs in any history of high-growth firms. It also makes it difficult to separate a good growth strategy from a very bad (but very lucky) one.

This period of extreme fragility and almost-certain failure is, by definition, fleeting. Organizations either hit on a long-shot or fail and disappear. A startup that escapes disaster actually grows more vulnerable to performance volatility. Only once it has grown sufficiently large or wealthy can it ignore volatility once more, albeit for different reasons (Ref et al., 2024). This is consistent with evidence that capital infusions into startups cause hiring behavior to conform to patterns usually reserved for more established organizations (Dahl & Klepper, 2015; Ouimet & Zarutskie, 2014) and provides another dimension to the treatment effect of venture capital.

Three HCM Regimes

Together, these suggest that human capital management has three distinct regimes with regard to worker volatility, as shown in Figure 3. When the organization's survival is deterministic (either because failure is impossible or because it is certain), volatility can be ignored altogether. When failure is possible, organizations should price volatility commensurate with the risk it induces. And when failure becomes the more likely outcome should workers deliver on expectations, the organization turns to volatility as a lottery ticket.

The boundary between the liability and lottery-ticket regimes is the state at which replacing a reliable worker with a volatile one of equal mean leaves survival unchanged, $S(W_t, N^r, N^v) = S(W_t, N^r - 1, N^v + 1)$.

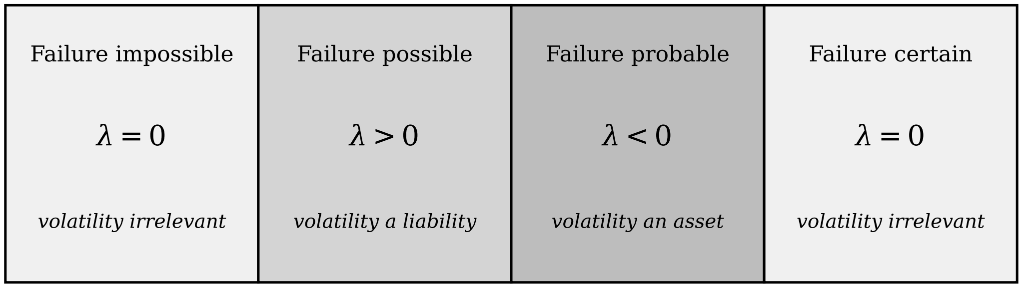

Figure 3: Three HCM Regimes with respect to worker volatility.

THE TAILS OF PERFORMANCE

One of the definitive roles of an organization is to coordinate the efforts of more than one person towards a common goal (Scott & Davis, 2015). And, in fact, the more complex and interconnected an activity, the greater the advantage conveyed by performing it within an organization compared to using market mechanisms. Thus far, workers have been independent and so the organizations' exposure to outlier performance, both good and bad days, was roughly symmetric. Again, some basic intuition from probability serves us well. The minimum is concave so swapping the reliable worker for a volatile one of equal mean strictly reduces expected output. The maximum is convex, so trading a deterministic worker for a volatile one raises its expectation. In other words, each of the two production functions presented here mechanically shaves off one tail of the worker's output, with implications for how the worker's performance is absorbed by the organization.

The Weakest Link and the Left Tail

Organizations differ in their inter-connectivity. In the mildest case, a set of interchangeable specialists benefit from sharing overhead: law firms employ accountants so that they don't have to spend attorney time on invoicing and billing. In a more extreme case, the production of complex products can mean that every role in the plant performs a crucial task without which the semiconductor, lithography machine, or aircraft cannot be completed. The Leontief production function best represents the latter pole, but also applies to a class of organizations in which the objective function is, itself, the elimination of negative outcomes (air traffic controllers, nuclear power plant operators, etc.) (Weick & Sutcliffe, 2001).

The first and most obvious difference in Leontief or assembly-line production is that volatility of any kind is punishingly expensive. One bad period from one worker can nullify an entire business, and so the organization requires an enormous premium for any risk at all. The larger the invoice, the more important good accounting becomes. The more expensive the machinery, the more important is every step in assembly and quality-assurance.

Under Leontief production, output is $A(N) \cdot \min(x_r, x_{v,1}, \ldots, x_{v,N^v})$, so the firm survives only if every worker's output (x_r or x_v) is above some floor: $-W_t/A(N)$. So long as this is true, the volatile replacement can only lower survival chances and the reliability premium is positive.[6]

Proposition 4 (Interdependence)**.** *Under Leontief production while $x_r > -W_t/A(N)$ the reliability premium is positive. As wealth grows, the premium converges to D.*

$$\lambda > 0, \qquad \lim_{W_t \to \infty} \lambda = D \geq 0.$$

This also (mostly) rules out the risk-seeking behavior by failure-prone firms under additive production (Proposition 3). In order for the organization to benefit from right-tail draws, it requires *all* employees to simultaneously over-perform against expectations. Except in very small firms, this is vanishingly unlikely.

Because wealth is independent of the production function, the wealth effect remains: resources make the volatile replacement slightly more palatable. When the firm already

[6]While this threshold is important for completeness, it functionally only matters when organizations are subject to some shock to wealth/resources or the scaling function. Absent those, the fact that the company exists and employs workers is evidence that it is operating with workers whose performance is above this threshold.

employs at least one volatile worker ($N^v \geq 1$), there exists a wealth level W_L^* at which $\Pr\big(x_v \geq -W_t/A(N)\big) = N^v/(N^v+1)$.[7] The reliability premium is increasing in wealth to that point, then declines towards D. When $N^v = 0$ (the replacement introduces the first volatile worker), the right-hand side is zero, no interior peak exists, and the premium declines monotonically toward D.

Proposition 5 (Interdependence, wealth)**.** *Under Leontief production with $N^v \geq 1$, the reliability premium rises in wealth until $W_t = W_L^*$, then falls to D:*

$$\frac{\partial \lambda}{\partial W_t} > 0 \quad (W_t < W_L^*),$$

$$\frac{\partial \lambda}{\partial W_t} < 0 \quad (W_t > W_L^*), \qquad \lim_{W_t \to \infty} \lambda = D \geq 0.$$

When $N^v = 0$ the interior peak disappears and λ falls monotonically to D.

The wealth result in proposition 5 also holds for improvements to a worker's mean performance (x_r).

However, the scale effect reverses. Larger organizations have more to lose and gain no benefit from "good days." The larger the workforce, the greater the value of future production. Reliable workers increase the likelihood of survival and volatile workers decrease it, widening the gap and raising the reliability premium. The premium also grows in headcount. Each added reliable worker increases the output that a single bad-day can destroy, so no number of workers ever makes even one volatile worker palatable.

Proposition 6 (Interdependence, scale)**.** *Under Leontief production the reliability premium grows large as the workforce expands:*

$$\lim_{N^r \to \infty} \lambda = \infty.$$

To any operations scholar, these results are intuitive and obvious. Variability at any

[7] This threshold exists for completeness. Most real-world organizations exist in the region above this point.

station in the production workflow damages throughput and creates periods of idleness/crunch. Early innovations in industrial management were largely directed at mitigating against or eliminating worker volatility to prevent expensive disruptions and bottlenecks (Hopp & Spearman, 2011; Taylor, 1911). Obviously, there are few large organizations that demonstrate this kind of fragility, but this is because those firms already make substantial investments in preventing this kind of cascading failure. These are well-known in operations but human capital management doesn't think of them as "costs" of selecting the wrong worker or expressions of the volatility tax.

The most immediate extension/implication for human capital is that organizations that cannot countenance failure should hire only the most consistent performers. If so, we would expect government agencies, utility companies, and payroll departments to be full of the kind of jobs where showing up and following the manual are the only requirements.[8]

There are further implications for the growth of organizations. Consider a startup founder who must work closely with their second employee. If the first is volatile (a common descriptor of entrepreneurs), then the second should be their opposite. A volatile entrepreneur with a bad business idea and a reliable co-founder can outperform one with an excellent idea and a volatile peer. In fact, if production is highly interconnected, all subsequent workers should be reliable: the premium will only grow as the organization does. At some point early in the organization's lifetime, the founder will need to consider whether it is better to hire reliable workers ad infinitum or instead invest in decoupling each function. The latter is likely to entail a substantial fixed-cost and thus suggests yet another potential treatment effect of venture capital (Hellmann & Puri, 2002).

Insurance and the Right Tail

Finally, I consider cases in which production output is entirely dependent on the single best input. Usually, this kind of competitive or tournament-style production function surfaces in

[8]Empirical corroboration of this hypothesis is outside the scope of this paper.

creative or innovative industries. Only one slogan becomes the brand asset. One actor gets to play the lead. One franchisee gets the territory. And only one invention receives a given patent. Given the non-cooperative nature of this work, it's not uncommon for each idea or entry in the contest to come from a separate organization. Still, many leading firms set up internal R&D functions which follow a similar logic. Some large technology companies, for example, make promotions contingent on shipping the best version of a desired product and in many sales organizations, only the top-performing agent earns the grand prize.

In competitive production, the organization only needs one Reliable-type employee. This worker gives a lower bound to the organization or team's output and indemnifies it from any and all risk of left-tail variance and, thus, failure, liquidation, or exhaustion. As before, there is a resource floor $-A(N)x_r$ above which the organization is guaranteed to survive, so long as $N^r = 1$. Because the single reliable worker can guarantee the organization's survival, their value is a material fraction of the entire business: $\lambda = [1 - S(W_t, N^r - 1, N^v + 1)]V(N) + D$. This premium rises as workers grow more volatile, because volatility raises the likelihood of failure without the reliable worker. However, this effect only exists over an interior band of wealth $\underline{W}_C < W_t < W_C^*$. Above W_C^* survival is effectively assured and added volatility only widens the output the reliable worker forgoes. Below $\underline{W}_C$ the failure threshold sits so close to the workers' mean that added volatility barely moves the probability of failure. In either tail the output cost dominates and the premium falls in volatility.

Though the first Reliable-type employee is important, they provide no other value to the organization besides insurance and benchmarking. Consider a team with only volatile workers. A larger pool of volatile workers reduces the probability that the organization fails and increases the expected return (and, thus, the cost of failure). There will be a point at which the probability that the maximum draw is less than the reliable worker's output is negligible, and so insurance adds no value. Likewise, a second reliable employee duplicates the functions of the first, adding no insurance value and occupying a slot that would otherwise produce positive value for the organization. Therefore, as wealth and scale increase, the reliable worker eventually becomes irrelevant.

Proposition 7 (Insurance)**.** *Under competitive production, while $N^r = 1$ and $W_t \geq -A(N)x_r$, the reliability premium rises with volatility on any interval where the insurance gain exceeds the difference in expected-output, falls with wealth, and is non-positive as wealth or the volatile workforce grow large:*

$$\frac{\partial \lambda}{\partial \sigma} > 0 \ \ (\underline{W}_C < W_t < W_C^*), \qquad \frac{\partial \lambda}{\partial W_t} < 0, \qquad \lim_{W_t \to \infty} \lambda = D \leq 0, \qquad \lim_{N^v \to \infty} \lambda \leq 0.$$

It follows that a second reliable worker is immediately a liability for the organization and every subsequent reliable worker produces increasingly negative value. This effect is exacerbated as the upside of the volatile alternative increases.

Proposition 8 (One is enough)**.** *Under competitive production, while $N^r \geq 2$ and $W_t \geq -A(N)x_r$, the reliability premium is non-positive, and decreasing in worker volatility and the number of reliable workers.*

$$\lambda = D \leq 0, \qquad \frac{\partial \lambda}{\partial \sigma} < 0, \qquad \Delta_{N^r} \lambda < 0, \qquad \lim_{\sigma \to \infty} \lambda = -\infty.$$

When organizational output depends only on the maximum draw, the organization places a premium on a worker's potential upside, rather than their expected performance (Proposition 7). In fact, the upside-oriented, tournament-style, R&D-focused organization has almost the exact same worker preference as the doomed startup (Proposition 3). This is not a surprising result. Organizations with highly-skewed payoffs, like venture capital funds, operate on almost the exact same principle when selecting companies (Bali et al., 2011; Cochrane, 2005; W. R. Kerr et al., 2014). Both have an effective cap on organizational downside (albeit for different reasons) and so can gamble on a worker's right-tail paying off.

However, unlike the additive and Leontief production functions, tournament production uses workers of each type in fundamentally different ways. If the volatile worker is a lottery ticket, the reliable worker is an insurance policy. They anchor the organization above the failure point, ensuring that even a perfect-storm of underperformance or bad ideas cannot sink the organization. Even in organizations with an unlimited ability to capture right-tail variance, there is still value in a low-performing and reliable employee. Colloquially, this person is sometimes referred to as the adult in the room (Hellmann & Puri, 2002; Wasserman, 2003).

Beyond insurance, the reliable worker may also make it easier to identify truly exceptional ideas by comparison (Gibbons & Murphy, 1990). Without the benchmark of an unexceptional but reliable worker, how can an organization tell whether a new design is good enough? In finance terms, a reliable worker makes it easier to identify the alpha (Jensen, 1968) of an idea or contribution from a more volatile employee.

Ideally a team would build from scratch with an understanding of volatility. The optimal sequence of workforce expansion for a small, innovative or creative organization will be to hire a single reliable employee as soon as possible, then focus only on the highest-upside available (Proposition 8). The same holds for team composition within larger organizations: almost everyone benefits from at least one level-head.

However, Proposition 7 also suggests that some teams can be built to such a size that insurance results from scale, rather than a balanced portfolio. In this case, no reliability is required or warranted, but the team is vulnerable. While it remains large and coherent, the law of large numbers protects against worker volatility. But should the team be split or otherwise reorganized such that the effective size and span of control shrink, there can be a sudden, material exposure to performance volatility risk. This is slightly counterintuitive: adding another manager should increase oversight and reduce worker volatility but may instead accidentally and invisibly eliminate the primary source of stability for the team's output.

Taken together, these results clearly identify the subset of organizations which should attend to volatility. Large, durable, wealthy organizations can ignore volatility altogether (Propositions 1 and 2). Failing organizations should seek it out (Proposition 3). And companies in between, where survival depends on the choice of worker, will require some compensation before replacing a steady performer with a volatile or uncertain worker. When a larger share of a worker's contribution is filtered through the performance of peers, the organization's preference for reliability increases (Proposition 4). And when one person's good day cures a multitude of ills, the organization will prefer employees with a high ceiling over those with a high floor (Proposition 7).

HUMAN CAPITAL PORTFOLIO MANAGEMENT

In a mean-only world, selection is an optimization problem. Given comparable information and constraints, organizations converge on the same workers because a higher expected contribution is all that matters. Differences in outcomes reflect operational effectiveness (signal extraction, screening cost, speed) instead of strategy (Mortensen & Pissarides, 1999; Spence, 1973; Stiglitz, 1975). Introducing within-person volatility creates mean–variance dilemmas in which the "right" choice depends on organization-specific (wealth, size, internal organization, prior hires, etc.) exposure to downside risk and ability to capture upside. Two rational organizations, facing the same worker pool but different Reliability Premiums, can choose differently and both be right.

This is similar to the classic Becker-Gerhart (1996) model in which human capital management supports sustained competitive advantage by creating a wedge between a worker's market value and their value to a firm (B. A. Campbell et al., 2012; Huselid, 1995; Lepak & Snell, 1999; Wright et al., 1994). Both rely on the inherent difficulty in imitating complex strategies (Rivkin, 2000), but volatility-informed HR strategy doesn't require organizations lock employees into a wage below their value or invest heavily in firm-specific human capital to generate persistent performance differences. Rather, value results from intertemporal smoothing of human capital risk. Even at market wages, an organization that is sophisticated with respect to performance volatility will outperform (or at least outlast) competitors in the long run.

However, where researchers have built a sophisticated and theoretically robust view of firm-specific human capital as a locus for strategic action, there is no comparable canon for stochastic worker performance. I argue that research and practice would benefit from a new research agenda, which I call Human Capital Portfolio Management (HCPM) and define as an approach to human resources and organizational design in which organizations make decisions with an explicit understanding of within-person performance volatility. Workers are not fixed producers of output, but stochastic assets whose realized performance fluctuates over time. Organizations, in turn, hold portfolios of such assets, with the objective of maximizing performance returns while managing exposure to human capital risk. In this, HCPM extends calls to treat human capital not as a single stock but as a portfolio of resources and their combinations (R. E. Ployhart et al., 2014), adding the dimension of within-person performance volatility those accounts set aside.

Though the findings above are largely consistent with other literatures on risk management and stochastic performance (Markowitz (1952) and Roy (1952) in finance; Taylor (1911) in operations), human capital resists management with traditional tools. For one, workers are non-tradeable and the volatility of a workforce is more costly to adjust than a portfolio of financial assets. An investor whose risk-appetite changes (or whose asset mix changes exogenously) can re-balance their portfolio by selling some assets and purchasing others. But a hiring manager cannot easily do the same. For another, workers are mobile and self-interested. A management intervention which suppresses variance but also strips worker agency is likely to lead to slacking, attrition, and the complete loss of whatever human capital investments have been made previously. In other words, it's not enough to be aware of worker volatility. We need researchers to identify the best ways to measure and manage it.

This research agenda has three pillars, each of which corresponds to an important abstraction or assumption made in the model above.

1) Measurement - Organizational/managerial ability to estimate a worker (or candidate's) performance distribution from observations, signals, and prior expertise. Includes both a worker's individual α and β and the within-team variance-covariance matrix.

2) Volatility Management - HR policies and managerial practices which improve individual worker consistency, buffer performance volatility, and enable the organization to capture value from the right-tail of worker performance distributions.

3) Portfolio Management - Design and composition of teams across roles and functions, as well as the machinery to modify the portfolio composition strategically in response to changes in worker characteristics, objectives, and environmental conditions.

Measurement

Perhaps the greatest challenge in implementing HCPM is that volatility is challenging to measure. For organizations and researchers alike, it can be difficult or impossible to distinguish between excellent performance and good luck. Worse, though individual volatility is somewhat stable in relation to peers, workers are not static. They change for better and for worse. Even with some understanding of a worker's baseline quality (though these signals are noisy as well), how should organizations determine whether performance in a period is representative of things to come? Or, without even the benefit of being able to observe prior performance, how should organizations think about hiring? Are there signals of reliability that are not also highly valued signals of quality or expected performance?

If evaluators rely on coarse proxies: tenure in role, uninterrupted employment, punctuality, or milestones like home ownership or parenthood, the drive to find reliable candidates might inject biases into HR practices. For instance, men receive a "fatherhood bonus" because their children are interpreted as a signal of stability and commitment but women with children face a motherhood penalty, likely due to presumed absenteeism and/or competing priorities (Correll et al., 2007). Likewise, age can be taken as steadiness, ethnicity, accent, or immigration status as unreliability, and frequent job changes as flightiness, regardless of actual performance data. Further research can provide alternative measures/signals and prevent these heuristics from amplifying existing biases.

This seems a daunting empirical challenge, but I should note that it is not radically different from efforts to determine signals of worker quality. The difference is simply that we've had a half-century of sophisticated research on the latter.

One opportunity of note: signals of volatility grow more obvious and will accumulate on a worker's resume over time. Conditional on industry and market dynamics, frequent job/firm/role changes, rapid promotions, geographic mobility, changing careers, and emerging skills may all be indicative of volatility. On the other hand, reliability is likely to look like none of these. Drawing from discussions with hiring managers and my own experience, I would suggest that we begin with signals such as time-in-grade. A highly reliable worker is never bad enough to be fired nor exceptional enough to be promoted. There may also be demographic or socio-economic features which operate on a worker's drive/motivation and so enforce discipline or inject chaos in their work habits. And, of course, researchers with access to firm-specific performance data may be able to find new and creative signals of reliability.

Volatility Management and Human Resources

Traditional performance management assumes that the role of HR interventions is to raise mean performance, reduce underperformance, or align behavior with organizational goals. But if we accept that some portion of observed variability is due to within-person volatility, then a new question emerges: How, if at all, do existing performance management practices affect the volatility of performance?

Management oversight, for instance, is generally assumed to suppress volatility—though sometimes at the cost of efficiency, autonomy, or innovation. But what of other interventions? We do not know whether performance feedback, coaching, incentives, or formal appraisal schemes reduce volatility, have no effect, or even increase it. The same applies to non-HR levers like team composition, job design, and reporting structure. Can organizations dampen volatility without suppressing performance or do more volatile workers require different performance management systems than their more consistent peers. Are they more responsive to incentives? More sensitive to feedback? Or simply less influenceable overall?

There are also questions about complementarity and role-specific sensitivity. Do volatile and reliable workers interact in productive ways (informal anchoring, peer/social regulation, or division of labor, etc.)? Do reliable coaches and mentors help temper their more volatile charges? If so, performance management becomes as much about team construction as individual oversight. Further, how does volatility shape or constrain performance management across roles and levels? Volatile output from an R&D scientist may be tolerated or even expected. Volatility from a low-level individual contributor might be costless to the organization and easily ignored. But, the same behavior from an auditor, security specialist, or plant manager might be grounds for dismissal. Ultimately, if present systems are not up to the task, it will fall to researchers to identify new processes and best practices to manage both volatility and mean performance.

Portfolio Management and Organizational Design

Finally, a key implication of this paper is that intentionally employing reliable or volatile employees is co-constitutive with strategic organizational design. Organizations choose their internal ordering and boundaries strategically as a way of minimizing costs or maximizing productivity and scale. This model suggests that they should also simultaneously consider the composition of their human capital portfolio in making these choices. The location of a function within the organization – its dependencies, relationships, management span of control, and coupling to other functions – should determine which kind of employee organizations seek, retain, and promote.

There are also questions about the reverse relationship. Conditional on the workers currently employed and the candidates available, how should organizations design their internal workflows? Are flatter organizations more vulnerable to worker volatility? Should production be modular, rather than tightly coupled? Should volatile workers be shunted to peripheral tasks? Does the existence of volatility bear on the boundaries of the firm? Would it make sense to outsource highly volatile tasks? Does the make-or-buy literature still hold if the resource in question is stochastic labor?

Finally, in considering the needs of the individual, more complications emerge. For one, a reliable employee provides a fundamentally different service to the team from their peers, but they do so unwittingly. Reliability is not a deliberate act, but rather an artifact of an individual's disposition, skill, and approach to work. An organization with competitive production benefits from this consistency but the value is largely invisible in day-to-day operations and, thus, difficult to manage or compensate. To single out the reliable worker for differential treatment is to threaten the behaviors that the organization values (S. Kerr, 1975). But treating them identically to their more erratic peers can be demoralizing for all involved (Greenberg, 1987). The reliable employee never wins the tournament. By construction, their work is never featured or selected for greater attention and yet they remain a member of the organization in good standing and an example to their peers. Neither employee type is likely to be entirely happy with this arrangement.

Model Extensions

Finally, two important extensions of this model are not explored here but are worthy of a brief discussion. First is the expansion of worker performance volatility to multiple organizations. I have thus far assumed that the manager's dilemma and, therefore, the Reliability premium is independent of the behavior of other organizations. In practice, the

HCM decisions of large incumbents shape the wages and availability of talent for new entrants. We can imagine a case in which a startup with additive production values reliability, but is unable to afford the wages set by a large incumbent with Leontief production and, therefore, a considerably higher reliability premium. Other organizations also affect the payoff function and the availability of resources. Startups engaging in a winner-take-all race to receive scarce venture capital may have no use for reliability, even if, in a vacuum, the risk-free worker would be the more responsible and rational choice.

A second extension concerns competition within the organization. In practice, teams and business units are neither homogeneous nor independent. Competition for promotions, coalition formation, and internal networks create complex and dynamic incentives which shape the manager's decisions distinct from those recommended by the organization-level reliability premium. As in the multi-organization case, the decisions of other managers directly alter the focal manager's tolerance for volatility within their team and their willingness to take risks with their own career and compensation.

In addition to promising interesting additions and caveats to this model, these extensions are important in developing our intuition around HCPM. It's likely that managers and organizations have some concept, already, of worker volatility, so the development of HCPM as a research agenda depends on the credible theoretical extension of this paper's very simple model.

CONCLUSION

There is something delightfully subversive in the idea that any organization, all else being equal, might rationally and correctly choose to hire a candidate who is simply "worse" than the alternative. It is the human capital management equivalent of backing Aesop's tortoise over the faster hare. And yet, the tortoise does win and the hare's propensity to nap or idle is a feature of its performance distribution. Perhaps in a rematch the speedier racer would be more focused. But what about the third race or the fourth? Would the hare's focus wane? Would boredom set in? Does the lure of the nap in the shade eventually grow too strong once again? And do oddsmakers take this into account? The tortoise may not win many races, but slow and steady will win some.

Researchers and practitioners alike have a blindspot with regard to performance. Despite evidence to the contrary, we overwhelmingly treat performance as a constant. For managers and entrepreneurs, that blindspot is an opportunity. A portfolio-style strategy that integrates talent selection and retention with organizational design, forecasting, and goal-setting is likely to be more performant and more difficult to imitate. For scholars, this is a call to deepen and broaden our pool of knowledge and better explain how to get the most out of human capital. Put another way: in a world of tortoises and hares, success goes to those who understand that the age-old parable is not a morality tale, but a lesson in building a portfolio for bad days.

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A Definitions and Assumptions

I begin by restating some notation from the model setup. In state (N^r, N^v), the firm retains the reliable worker. In state $(N^r - 1, N^v + 1)$, the firm replaces that worker with a volatile worker. Total headcount is unchanged at $N = N^r + N^v$. The firm survives the period when $W_{t+1} = W_t + Q(N^r, N^v) \geq 0$, i.e. output clears the threshold $-W_t$, so

$$S(W_t, N^r, N^v) = \Pr\big(Q(N^r, N^v) \geq -W_t\big). \tag{A.1}$$

With a volatile worker present ($N^v \geq 1$) output has a density and $\partial S/\partial W_t = f(-W_t; N^r, N^v) \geq 0$. When all workers are reliable ($N^v = 0$), output is $N^r x_r$ and S steps at $W_t = -N^r x_r$. The continuation value satisfies $V(N) > 0$ and $\sup_N V(N) < \infty$, and the scale function satisfies $A(N) > 0$, $A(N+1) > A(N)$, and $A(N) \to \infty$.

Definition 1 (Reliability premium)**.** The reliability premium is

$$\lambda = \big[S(W_t, N^r, N^v) - S(W_t, N^r - 1, N^v + 1)\big]V(N) + D, \tag{A.2}$$

where

$$D \equiv E[Q(N^r, N^v)] - E[Q(N^r - 1, N^v + 1)]. \tag{A.3}$$

Definition 2 (Volatile performance)**.** Reliable workers produce $x_r > 0$. Volatile workers produce

$$x_v = x_r + \sigma z, \qquad E[z] = 0, \qquad \mathrm{Var}(z) = 1, \tag{A.4}$$

where z has a fixed continuous distribution with density f_z and distribution function F_z. Volatile-worker draws are independent across workers and independent of W_t.

There is no consensus on the shape of worker performance distributions. Lab and field studies point variously to Gaussian, log-normal, exponential, and heavy-tailed forms. In practice the exact shape may not matter. It is person-role specific, and few organizations have the data or the analytical capacity to pin it down. I therefore build the model, and state the propositions, to hold across shapes. I specify only that volatile performance is a location-scale family, which yields results that hold whenever more spread widens both tails. This needs one assumption, that two firm-output densities cross at two points (as if both had single peak, not multiple humps), and two lemmas.

Assumption 1 (Additive single crossing)**.** Under additive production, let f_R, f_V be the densities of the retained and replacement outputs $Q_R = Q(N^r, N^v)$ and $Q_V = Q(N^r - 1, N^v + 1)$. They share the mean $\mu_Q = Nx_r$. The densities cross at two points $c_L < c_U$ straddling the mean, with $f_R > f_V$ on (c_L, c_U) and $f_R < f_V$ outside $[c_L, c_U]$.

The difference in expected output, D, depends on the production function. Under additive production $D = 0$, since the two worker types share the mean x_r. Under Leontief and competitive production D is signed, and the sign follows from the curvature of the minimum and the maximum.

Lemma 1 (Curvature)**.** *For any convex g, $E[g(x_v)] \geq g(x_r)$ and $E[g(x_r + \sigma z)]$ is weakly increasing in σ. For any concave g, the inequalities reverse.*

Proof. This follows from Jensen's inequality because $E[x_v] = x_r$. If $\sigma_2 > \sigma_1$, then $x_r + \sigma_2 z$ is a mean-preserving spread of $x_r + \sigma_1 z$, so the expectation of any convex function weakly increases with σ. The concave case is analogous. □

Finally, survival turns on clearing a failure threshold, so the last piece of machinery used in the proofs describes how volatility shifts the chance of clearing a target.

Lemma 2 (Tail monotonicity)**.** *For any target level c,*

$$\Pr(x_v \geq c) = 1 - F_z\left(\frac{c - x_r}{\sigma}\right). \tag{A.5}$$

Where f_z is positive at $(c - x_r)/\sigma$,

$$\frac{\partial}{\partial\sigma} \Pr(x_v \geq c) = f_z\left(\frac{c - x_r}{\sigma}\right) \frac{c - x_r}{\sigma^2}. \tag{A.6}$$

Thus the tail probability decreases in σ for $c < x_r$, is constant at $c = x_r$, and increases in σ for $c > x_r$.

B Proofs

B.1 Additive production

Under additive production, output is a sum, so the shared worker mean leaves expected output unchanged: $D = 0$ and

$$\lambda = \big[S(W_t, N^r, N^v) - S(W_t, N^r - 1, N^v + 1)\big]V(N). \tag{B.1}$$

Proof of Proposition 1 (Scale effect). The scope condition $S(W_t, N^r, N^v) > S(W_t, N^r - 1, N^v + 1)$ and $V(N) > 0$ give $\lambda > 0$ by (B.1). As $N^r + N^v \to \infty$, the $N - 1$ workers common to both states concentrate their combined output around its mean, so replacing one reliable worker with one volatile worker shifts survival by a vanishing amount. With $V(N)$ bounded, $\lambda \to 0$. $\square$

Proof of Proposition 2 (Wealth effect). For $N^v \geq 1$, differentiating (B.1) with $\partial S/\partial W_t = f(-W_t; \cdot)$ gives $\partial\lambda/\partial W_t = [f_R(-W_t) - f_V(-W_t)]V(N)$. Above $W_A^* = -c_L$, Assumption 1 gives $f_R(-W_t) < f_V(-W_t)$, so $\partial\lambda/\partial W_t < 0$. With $\lambda \to 0$ as $W_t \to \infty$, $\lambda > 0$ there.

For $N^v = 0$ the retained firm's output is the fixed $N^r x_r$, so it survives for certain above $W_A^* = -N^r x_r$. There $\lambda = [1 - S(W_t, N^r - 1, 1)]V(N)$ is positive, falls in W_t $(\partial\lambda/\partial W_t = -f_V(-W_t)V(N) < 0)$, and tends to zero. $\square$

Proof of Proposition 3 (Imminent failure). If $S(W_t, N^r, N^v) < S(W_t, N^r - 1, N^v + 1)$, then (B.1) and $V(N) > 0$ imply $\lambda \le 0$. In this region the threshold $-W_t$ exceeds the common mean $\mu_Q = N x_r$.

For $N^v \ge 1$, differentiating (B.1) in σ gives

$$\frac{\partial \lambda}{\partial \sigma} = \left[f_R(-W_t) - f_V(-W_t) \right] \frac{-W_t - \mu_Q}{\sigma} V(N),$$

so $\partial\lambda/\partial\sigma$ has the sign of $f_R(-W_t) - f_V(-W_t)$. By Assumption 1, $f_R < f_V$ above the upper crossing c_U. The outputs are location-scale in σ, so $c_U = \mu_Q + \sigma a_0$ for a fixed $a_0 > 0$ and $c_U \to \mu_Q$ as $\sigma \to 0$. Since $-W_t > \mu_Q$, small enough σ makes $-W_t > c_U$, so $f_R(-W_t) < f_V(-W_t)$ and $\partial\lambda/\partial\sigma < 0$.

For $N^v = 0$, the retained output $N^r x_r = \mu_Q$ is deterministic, so $S(W_t, N^r, 0) = 0$ throughout the region and constant in σ. The replacement survives if and only if $x_v \ge -W_t - (N^r - 1)x_r$, a threshold above x_r, so $S(W_t, N^r - 1, 1)$ rises in σ by Lemma 2. Hence $\partial\lambda/\partial\sigma < 0$ for all σ. □

B.2 Leontief production

Under Leontief production,

$$Q(N^r, N^v) = A(N) \min(x_r, x_{v,1}, \ldots, x_{v,N^v}).$$

The minimum is concave in the replaced draw, so $D \ge 0$ (Lemma 1), and $D > 0$ for $\sigma > 0$ since the spread strictly lowers the expected minimum. Let

$$\tau \equiv -W_t/A(N), \qquad p \equiv \Pr(x_v \ge \tau).$$

If $x_r \geq \tau$, the retained firm survives if and only if all N^v volatile workers clear τ, and the replacement firm survives if and only if all $N^v + 1$ volatile workers clear τ. Therefore

$$\lambda = V(N)p^{N^v}(1-p) + D \qquad (x_r \geq \tau). \tag{B.2}$$

Proof of Proposition 4 (Interdependence). By (B.2), λ is a nonnegative survival term plus $D \geq 0$ (above), so $\lambda \geq 0$. For $\sigma > 0$, $D > 0$, so $\lambda > 0$. As $W_t \to \infty$, $\tau \to -\infty$ and $p \to 1$. The survival term $p^{N^v}(1-p)$ goes to zero, leaving $\lambda \to D \geq 0$. □

Proof of Proposition 5 (Interdependence, wealth). Since D does not depend on W_t, differentiating (B.2) gives

$$\frac{\partial \lambda}{\partial W_t} = V(N)p^{N^v-1}\big[N^v - (N^v+1)p\big]\frac{\partial p}{\partial W_t}. \tag{B.3}$$

Higher wealth lowers τ, so $\partial p/\partial W_t \geq 0$. For $N^v \geq 1$, the sign of (B.3) is positive when $p < N^v/(N^v+1)$ and negative when $p > N^v/(N^v+1)$. The premium therefore peaks at W_L^* satisfying

$$\Pr(x_v \geq -W_L^*/A(N)) = \frac{N^v}{N^v+1}.$$

As $W_t \to \infty$, $p \to 1$, the survival term vanishes, and $\lambda \to D \geq 0$. If $N^v = 0$, the survival term $1-p$ decreases in wealth, so no interior peak exists and λ falls monotonically to D. □

Proof of Proposition 6 (Interdependence, scale). By (B.2), $\lambda = V(N)p^{N^v}(1-p) + D$. The survival term is bounded because $V(N)$ is bounded. The expected-output term is $D = A(N)\delta$, where δ is the difference between the expected minima in the retained and replacement states before scaling by $A(N)$. For fixed N^v and $N^r \geq 2$, δ does not depend on N^r and, for $\sigma > 0$, is strictly positive (the strict $D > 0$ above). Since $A(N) \to \infty$, $D \to \infty$. Therefore $\lambda \to \infty$ as $N^r \to \infty$. □

B.3 Competitive production

Under competitive production,

$$Q(N^r, N^v) = A(N)\max(x_r, x_{v,1}, \dots, x_{v,N^v}).$$

The maximum is convex in the replaced draw, so $D \leq 0$ (Lemma 1), and $D < 0$ for $\sigma > 0$ since the spread strictly raises the expected maximum. Retain the previously introduced notation $\tau = -W_t/A(N)$ and $p = \Pr(x_v \geq \tau)$. If $x_r \geq \tau$ and $N^r = 1$, the retained firm survives for certain, while the replacement firm fails only if all $N^v + 1$ volatile workers fall below τ. Thus

$$\lambda = V(N)(1-p)^{N^v+1} + D \qquad (N^r = 1,\ x_r \geq \tau). \tag{B.4}$$

If $x_r \geq \tau$ and $N^r \geq 2$, both states retain at least one reliable worker, so both survive for certain and

$$\lambda = D \leq 0. \tag{B.5}$$

Proof of Proposition 7 (Insurance). For $N^r = 1$ and $x_r \geq \tau$, equation (B.4) gives

$$\frac{\partial \lambda}{\partial \sigma} = -(N^v+1)V(N)(1-p)^{N^v}\frac{\partial p}{\partial \sigma} + \frac{\partial D}{\partial \sigma}.$$

Since $\tau \leq x_r$, Lemma 2 gives $\partial p/\partial\sigma \leq 0$. Lemma 1 gives $\partial D/\partial \sigma < 0$. Hence the premium rises with volatility exactly when

$$(N^v+1)V(N)(1-p)^{N^v}\left(-\frac{\partial p}{\partial \sigma}\right) > -\frac{\partial D}{\partial \sigma}. \tag{B.6}$$

When nonempty, the set of wealth levels satisfying (B.6) is denoted $(\underline{W}_C, W_C^*)$. At the floor $\tau = x_r$, Lemma 2 gives $\partial p/\partial\sigma = 0$. As $W_t \to \infty$, $p \to 1$ and $(1-p)^{N^v} \to 0$. Thus the insurance gain vanishes at both ends of the region. If (B.6) never holds, $\partial\lambda/\partial\sigma < 0$ throughout.

For wealth, D is constant in W_t, and

$$\frac{\partial \lambda}{\partial W_t} = -(N^v + 1)V(N)(1-p)^{N^v} \frac{\partial p}{\partial W_t} \leq 0,$$

with strict inequality wherever the volatile output has positive density at τ. As $W_t \to \infty$, $p \to 1$ and $\lambda \to D \leq 0$. For fixed $p < 1$, as $N^v \to \infty$, $(1-p)^{N^v+1} \to 0$, so again $\lambda \to D \leq 0$. $\square$

Proof of Proposition 8 (One is enough). If $N^r \geq 2$ and $x_r \geq \tau$, both states contain at least one reliable worker, so both survive for certain. The survival difference is zero, and (B.5) gives $\lambda = D \leq 0$.

Only D moves with σ. Since the maximum is convex in the replaced draw, Lemma 1 gives $\partial D/\partial \sigma \leq 0$, strictly for $\sigma > 0$, so $\partial \lambda/\partial \sigma < 0$. For headcount, write $D = A(N)\eta$, where

$$\eta = E \max(x_r, x_{v,1}, \ldots, x_{v,N^v}) - E \max(x_r, x_{v,1}, \ldots, x_{v,N^v+1}).$$

For $\sigma > 0$, $\eta < 0$ (the spread strictly raises the expected maximum). For fixed N^v, η is independent of N^r, while $A(N)$ is strictly increasing. Hence $\Delta_{N^r}\lambda = \Delta_{N^r} D < 0$. Finally, as $\sigma \to \infty$, the expected volatile maximum diverges, so $\eta \to -\infty$ and $\lambda \to -\infty$. $\square$

C Numerical Illustration

The results are not Gaussian-specific. This illustration fixes a Gaussian volatile law only to put numbers to the reliability premium. Workers are paid \$100,000 per period. Their expected output is worth \$105,000, so each clears $x_r = \$5,000$ net. A volatile worker's performance is normal around that mean with standard deviation \$30,000. The firm holds no reserves ($W_t = 0$), faces no resource shocks, and has continuation value equal to current expected output.

Consider a firm with two reliable workers. Its output is certain at \$10,000, so it survives.

Replacing one reliable worker with one volatile worker leaves expected first-period output unchanged at \$10,000, but output is now normal with standard deviation \$30,000. The failure probability is

$$\Phi\left(\frac{0 - 10,000}{30,000}\right) = \Phi(-1/3) \approx 0.37.$$

The loss runs through survival, not expected output. The firm keeps its continuation value with probability about 0.63, so expected continuation value falls to about $\$10,000 \times 0.63 = \$6,300$. Keeping the worker reliable is therefore worth about \$3,700. The premium falls with reserves and scale. With \$10,000 on hand, the failure probability falls to $\Phi(-2/3) \approx 0.25$, and the premium is about \$2,500. In a firm of twenty reliable workers with \$20,000 on hand, replacing one reliable worker with one volatile worker leaves failure all but impossible, $\Phi(-4) \approx 0.00003$, and the premium is about \$3.

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