Managing High Worker Turnover in Manufacturing*

(Extended Abstract)

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Leveraging a uniquely rich dataset drawn from China-based final assembly, testing, and packaging (FATP) facilities producing millions of units of consumer electronic goods per week, we study the drivers and consequences of high worker turnover in a large-scale production setting. By combining rolling-horizon production schedules, the compensations and assignments of 52,214 individual workers, and the weekly volume and yield outcomes of their assigned production lines, we present evidence that manufacturing lines’ productivities are uniquely susceptible to employee turnover: conservatively, the manufacturer’s material costs incurred from diminished yields alone can approach $58 million ([ ]% of material costs) over the production life cycle of a single device model, plus potential losses of additionally twice as much when resulting in lost sales. Critically, we find that turnover depresses a line’s cohesive productivity by disrupting workflows, which is left unab- dressed when firms seek to assess and even compensate employees by their individual productivities alone. Interestingly, the manufacturer faces operational trade-offs in managing a heterogeneous, turnover-prone workforce: only one of two primary segments values the retention of peers. Applying advances in approximate dynamic programming and reinforcement learning, we estimate and simulate for counterfactuals an experienced-based equilibrium model of heterogeneous worker turnover. Using this framework, we prescribe policies for the firm to manage its endogenous staffing to optimize production.

Key words: Data-driven workforce planning; Empirical operations management; Employee turnover; Experience-based equilibrium; Productivity; Stochastic optimization; Structural estimation.

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Pioneered by Frederick Taylor at the turn of the 19th century into the 20th, classical scientific management rooted its early foundations in the detailed measurement of labor efficiency and productivity in manufacturing and production. While the study and management of production and supply chains has considerably advanced, the then-commonplace phenomenon of rapid worker turnover (annually 184% for US manufacturing in 1918) has re-emerged as a particularly salient and thorny challenge for modern production processes. Today’s largest manufacturers employ hundreds of thousands to millions of workers annually, yet the standing workforce is replaced three times over within a single year – that is, an annual voluntary turnover rate exceeding 300% – at some of the China-based production facilities studied in this paper. In quarterly consumer revenue, these same facilities output tens of billions USD of complex consumer electronic goods.

Presently, elevated turnover pervades all levels of the modern supply chain. Shih (2014) (MIT Sloan Management Review) places significant turnover as the top-of-list concern for US manufacturers seeking to “reshore” production, with GE’s US-based Appliance Park “hiring] 6,500 workers to yield the required 2,500 employees to begin volume production” and facing a further 23% turnover rate for the year. One of the largest US wholesale distributors of pharmaceuticals reported to us that annual voluntary turnover at its distribution centers had risen from historically single-digit percentages to upwards of 40% annually, even as extensive automation, data-driven feedback, and incentive-based compensation have boosted labor productivity. More generally, managing turnover is critical to operations across the spectrum of industries, including retail services (67% annual turnover), transport (74% for truck operators), hospitality (70%), call centers (30-45%), warehousing (40%), and staffing-sensitive healthcare (19.2%). Even against this common backdrop, the escalating turnover in large-scale manufacturing is exceptional.

Assembling and employing a uniquely rich proprietary dataset, our study aims to understand, both descriptively and prescriptively, the drivers and productive consequences of high worker discussions. Seminar participants at the Wharton/Penn Industrial Organization lunch and 2017 INFORMS Annual Meeting provided helpful feedback.
turnover in modern, large-scale production. In these settings, workers individually complete routine tasks rapidly and repetitively, but remain importantly inter-linked by workflows. Drawn from final assembly, testing, and packaging (FATP) facilities that output millions of units of consumer electronic goods per week, our panel dataset combines (A) human-resources data detailing the characteristics, assignments, and compensations of 52,214 individual workers from hire to turnover, (B) granular volume and yield outcomes from individual production lines, and (C) the firm’s rolling-horizon production plans and forecasts. We construct this dataset by reconciling and integrating four distinct and separately maintained sets of extensive business records.

By thus drawing on comprehensive data, our contributions are threefold.

• First, we characterize and quantify the effects of rapid worker turnover on manufacturing productivity. This empirical undertaking is challenging, because the firm employs a pair of operational tactics designed to mitigate, hence obscuring, turnover’s impact on productivity: (A) first reducing a troubled line’s operating speed to protect yields; and (B) second adjusting the staffing of workers (and thus experience levels) across production lines. The firm applies these costly levers endogenously in response to lines’ productivity issues. To identify turnover effects, we employ two independent empirical strategies, one of which exploits demand-based updates to the firm’s weekly production targets as critical instrumental variables. Our most conservative estimates find that the manufacturer’s lost-material costs incurred from diminished production yields alone can approach $58 million for the single device model we study, with potential losses of additionally twice as much in foregone margin per unit when resulting in lost sales.

• As our second contribution, we study the drivers of worker turnover in modern assembly manufacturing. In particular, workers decide on the timing of when to depart the firm based on their expectations about compensation, the workplace states of their assigned production lines, and the turnover decisions of their line co-workers. To examine these inherently dynamic decisions and their antecedents, we estimate an experience-based equilibrium model (Fershtman and Pakes (2012)) of turnover, revealing how workers anticipate unpleasant or rewarding future states that
include the turnover of their line peers. Interestingly, we find that the firm must manage two heterogeneous subgroups of workers, where (A) the first values staffing stability, suffering upon the rapid turnover of their line peers, and (B) the second espouses a more transactional posture, by closely considering hours of labor against compensation received. The latter subgroup proves difficult to retain as workers gain experience.

- Thirdly, we prescribe how a firm should decide whether (A) to reduce or control its employee turnover or (B) to instead mitigate its effects on production. In practice at the facilities we study, managers receive little guidance on the optimal mix of control versus mitigation and often suspect that they may undervalue the benefit of retaining worker experience. This challenging control problem (A) is embedded within a stochastic production planning problem with a rolling horizon and (B) must incorporate the stochastic, dynamic game in which workers make individual turnover decisions weekly. Exploiting recent advances in approximate dynamic programming and reinforcement learning with “deep exploration”, we develop computationally tractable methods of simulating and optimizing over complex, dynamic policies (including allocating tens of thousands of individual employees weekly to specific lines). We then use this framework to evaluate and recommend how a manufacturer should plan production while regulating its endogenous workforce turnover through compensation and workload management.