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# Does Lean Improve Labor Standards? Management and Social Performance in the Nike Supply Chain

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**Abstract.** This study tests the hypothesis that lean manufacturing improves the social performance of manufacturers in emerging markets. We analyze an intervention by Nike, Inc., to promote the adoption of lean manufacturing in its apparel supply chain across 11 developing countries. Using difference-in-differences estimates from a panel of more than 300 factories, we find that lean adoption was associated with a 15 percentage point reduction in noncompliance with labor standards that primarily reflect factory wage and work hour practices. However, we find a null effect on factory health and safety standards. This pattern is consistent with a causal mechanism that links lean to improved social performance through changes in labor relations, rather than improved management systems. These findings offer evidence that capability-building interventions may reduce social harm in global supply chains.

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**Keywords:** corporate social performance • global supply chains • lean manufacturing • human resource management • labor standards

## 1. Introduction

Corporate social performance has become an imperative in strategic management. As stakeholders have grown increasingly adept at pressuring firms surrounding the social impacts of their activities (Porter and Kramer 2006), scholars have linked corporate social performance to a variety of positive outcomes, including improved access to finance (Cheng et al. 2014), the ability to attract talented employees (Turban and Greening 1997, Bhattacharya et al. 2008), increased recommendations from stock analysts (Luo et al. 2013), and improved risk management (Koh et al. 2014). Social performance is particularly important for firms transacting in foreign jurisdictions where their social license to operate may be subject to the influence of powerful local stakeholders (Kytile and Ruggie 2005, Henisz et al. 2014).

A wide variety of multinational enterprises—including industry leaders in retail (Walmart, Target, Ikea), electronics (Apple, Microsoft, HP), toys (Mattel, Hasbro), soft drinks (Coca Cola), and the 10 most valuable apparel brands<sup>1</sup>—have responded by adopting compliance programs to enforce social standards in their global supply chains. The goal of these programs is to improve the social performance of upstream business partners, primarily in developing countries. They seek to address stakeholder concerns about the social impact of production and to reduce reputational risk

for lead firms (Locke 2013). Yet despite widespread adoption of social compliance programs, research has repeatedly shown that they yield only limited improvements in social performance (Barrientos and Smith 2007, Egels-Zandén 2007, Locke et al. 2007b, Lund-Thomsen et al. 2012). Weak social compliance means that important labor, safety, and environmental standards are violated in the production of popular consumer goods, placing employees' health and economic well-being at risk. From the managerial perspective, ineffective compliance programs threaten corporate social performance and its associated benefits. Socially irresponsible practices in the supply chain expose lead firms to the risk of negative financial shocks associated with activist campaigns (King and Soule 2007) and the disclosure of socially harmful behavior (Klassen and McLaughlin 1996, Flammer 2013).

This article explores an alternative approach to improving social performance in global supply chains. We study the relationship between management practices and social performance among apparel manufacturers in emerging markets. The global apparel industry employs over 25 million in low- to middle-income countries (International Labour Organization 2005) and represents an important entry point for developing countries to global trade in manufactures (Gereffi 1999). Since 2008, Nike, Inc.—an international leader in the design and retail of athletic apparel,

footwear, and equipment—has promoted the adoption of lean manufacturing in its apparel suppliers. This program provided training in lean manufacturing to supplier management, encouraged the adoption of these management practices, and verified that supplier production lines satisfied a set of lean standards. Adoption of this production system required significant changes to the organization of production, worker participation, and management systems.

What are the effects of lean manufacturing on social performance? Although the proximal objectives of lean are to improve manufacturing performance, we hypothesize that replacing traditional manufacturing practices with lean will also result in improved social performance. We posit two mechanisms, which may operate in tandem, that link lean manufacturing to improved workplace standards. The labor relations mechanism holds that increased efforts to motivate and retain production workers under lean manufacturing result in improved terms of employment, such as wages and benefits. The management systems mechanism posits that new managerial capabilities lower the costs of complying with social performance standards.

We estimate the effects of lean on social performance using panel data from more than 300 factories across 11 developing countries between 2009 and 2013. Drawing on difference-in-differences estimates, we find that the lean intervention was associated with significant improvements in factory social performance. Adoption of lean manufacturing practices led to a 15 percentage point reduction in noncompliant labor grades.<sup>2</sup> This finding is robust to alternative specifications, including controls for divergent labor market trends across countries, controls for increased monitoring and enforcement by Nike, and an examination of pretrends among the lean adopters. We estimate a modest effect on health, safety, and environmental compliance, but it is imprecisely estimated and more sensitive to specification choices. This pattern of improvements is consistent with the hypothesis that changes in labor relations associated with high-involvement work link lean to improved labor standards. We also find heterogeneity in workplace improvements by country; although the intervention significantly raised labor compliance in India and Southeast Asian countries, factories in China showed no improvement.

Our work contributes to a deeper understanding of how multinational strategy affects social outcomes in global markets in three ways. First, our findings represent the first quantitative evidence linking capability building to improved social performance in global production. Although a growing scholarly consensus affirms the importance of corporate social performance, major questions remain about how to achieve this performance in global production networks. Capability-building interventions are increasingly promoted by both global buyers and external

stakeholders to improve supply chain social compliance (Oxfam 2010, Hurst et al. 2011), but empirical evidence on their impact is limited and ambivalent, leading to calls for new empirical work (Lund-Thomsen and Lindgreen 2014). Our examination of over 300 firms in 11 developing countries and our use of unit fixed effects for econometric identification allow us to improve both in terms of internal and external validity on previous research on management practices and social compliance, which has relied on small samples and cross-sectional analysis (Locke et al. 2007a).

Second, this study contributes new understanding about the social effects of modern management in globalized production. Various studies have documented the effects of lean and related high-performance work systems on business outcomes, including productivity (MacDuffie 1995, Dunlop and Weil 1996, Ichniowski et al. 1997), product quality (MacDuffie 1995, Bloom et al. 2013), and financial performance (Huselid 1995). However, research on the social consequences of lean has focused on wages and worker motivation (Appelbaum 2000, Cappelli and Neumark 2001, Osterman 2006) or environmental performance (King and Lenox 2001) in advanced economies. We instead study lean's effect on compliance with workplace social standards, which include wages and benefits but also encompass a broader set of practices intended to protect employees and local communities. By investigating this relationship among manufacturers in emerging markets, we contribute to a debate on the effects of lean in the developing world. Some research suggests that pressures to adopt lean manufacturing and develop fast turnaround capabilities have led to a deterioration of working conditions in emerging market suppliers. Managers lacking the resources to effectively implement modern manufacturing systems shift the costs of flexible production onto the workforce in the form of longer hours, lower wages, and more precarious employment (Dhanarajan 2005, Raworth and Kidder 2009). However, these claims have yet to be subjected to quantitative hypothesis testing. Our findings offer evidence that lean manufacturing can be meaningfully implemented in the context of export manufacturing in emerging markets and that its adoption yields benefits for social performance, linking economic upgrading to social upgrading in global supply chains (Barrientos et al. 2011). Most importantly, because these management practices stand to benefit buyers, suppliers, and workers, lean capability building promises greater sustainability than traditional social compliance programs.

Finally, these findings suggest a strategy for reconciling tension between the market imperatives of modern supply chain management and social performance. Contemporary sourcing strategies such as competitive costing, reduced lead times, and smaller

order sizes shift risks onto suppliers and their workforces, thereby undermining key goals of social compliance programs (Dhanarajan 2005, Barrientos 2013, Riisgaard 2009, Locke 2013). The global apparel industry, where contemporary sourcing practices have been argued to be particularly deleterious to labor outcomes (Anner et al. 2012), is a key case for addressing the tension between sourcing strategy and supplier social outcomes. A major goal of the intervention we study was to improve supplier capabilities to deal with sourcing trends toward smaller orders and more rapid turnaround. We show that adopting management systems to meet these demands also led to improved social outcomes. Our results suggest that contemporary trends in supply chain strategy need not depress working conditions so long as emerging market manufacturers possess appropriate management capabilities. At the same time, we show that promoting the adoption of new management practices is a major undertaking. In the case we examine, it involved securing multiyear commitments of support from supplier leadership, establishing a dedicated training facility, and engaging intensively with suppliers' operations personnel.

In the following section, we introduce supply chain social compliance programs and the challenges of aligning business practice with social performance goals in global production. We proceed to describe Nike's intervention to promote lean manufacturing, developing our hypothesis that lean manufacturing will yield improved workplace standards. After describing our data and empirical strategy, we present our main finding: lean adoption produced a substantial reduction in poor compliance grades associated with wage and work hours violations. The final section discusses the limitations of this study and implications for future research and management practice.

## 2. Managing Social Performance in Global Production

Global supply chains link thousands of firms across multiple political and economic boundaries. The diffusion of global supply chains in an array of different industries—including apparel, electronics, footwear, food, toys, and others—has provided developing countries with needed investment, employment, technology, and access to international markets. At the same time, the social and environmental consequences of this pattern of economic development have provoked controversies over the role of global buyers and their local suppliers, often seen as exploiting low wages and regulatory laxity to produce low-cost goods at the expense of workers' welfare. As publicized by activists and social movements (Harrison and Scorse 2010, King and Pearce 2010), child labor, hazardous

working conditions, excessive working hours, and poor wages plague many workplaces in the developing world (Verité 2004, Pruett et al. 2005, Connor and Dent 2006, Kernaghan 2006). These revelations create scandal and embarrassment for the global companies that source from these factories and farms.

In the absence of a strong system of global justice (Cohen and Sabel 2006) and given the limited ability (perhaps willingness) of many national governments to enforce their own regulations, an array of actors—including transnational NGOs (Keck and Sikkink 1998, Seidman 2007), global corporations and industry associations (Hauffer 2001, Bartley 2007, O'Rourke 2003, Ruggie 2008, Reich 2007), and some developed country governments (Bartley 2007)—began to promote private initiatives aimed at establishing and enforcing labor and environmental standards in global supply chains. We refer to these initiatives as forms of private regulation (Vogel 2008, 2010).

The prevalent model of private regulation involves establishing supply chain "Codes of Conduct." In theory, these standards are enforced on upstream suppliers through private audits and the threat of withholding orders from noncompliant factories. However, a decade of research has demonstrated the limitations of this strategy for enforcing labor standards. Notwithstanding years of effort and significant investments by global corporations in developing more comprehensive monitoring tools, hiring growing numbers of internal compliance specialists, conducting thousands of factory audits, and working with external consultants and NGOs, working conditions and labor rights have improved among some supplier factories but have stagnated or even deteriorated in many others (Locke 2013). Although pressure generated by anti-sweatshop campaigns has improved wages in some cases (Harrison and Scorse 2010), the scholarly literature on private regulation has generally found persistent noncompliance in a variety of workplace standards (Barrientos and Smith 2007, Egels-Zandén 2007, Locke et al. 2007a). Despite private initiatives to equalize minimum workplace standards across countries, domestic regulatory institutions and civil society remain key predictors of social compliance in global supply chains (Distelhorst et al. 2014, Toffel et al. 2015).

One important critique of these programs is that they decouple compliance activities from core business practices and thereby limit their impact on supplier social performance. When needs for external legitimacy diverge from market demands, firms may design compliance regimes that conflict with other business processes, a decoupling that has been observed in other corporate ethics regimes (Weaver et al. 1999, MacLean and Behnam 2010). Within the global buyers that implement compliance programs, sourcing decisions are often decoupled from the enforcement of

private regulation, resulting in tension between these two functions. It is not uncommon to hear complaints from social compliance managers that their mission is not taken seriously by their colleagues in purchasing departments (Harney 2008, p. 213). For their part, suppliers complain that, despite lip service paid to ethical compliance, sourcing decisions appear to remain guided by traditional business considerations, such as price, quality, or turnaround (Ruwanpura and Wrigley 2011). Some buyers have publicly acknowledged that their own sourcing practices—including the proliferation of styles, last-minute order changes, poor forecasting, and overloading supplier capacity—contribute to the very social performance problems that compliance programs attempt to remediate (Nike, Inc. 2012, Locke 2013).

In light of the limitations of private regulation, we study a supply chain intervention that focuses on developing the management capabilities of suppliers, rather than enforcing standards through sourcing decisions. The immediate goal of capability building is not to monitor and incentivize socially responsible behavior, but rather to change suppliers' day-to-day managerial practices in ways that may also support improved social performance. Capability building for social performance has been pursued across a variety of industries (Locke 2013), but claims of impact have yet to be subjected to quantitative hypothesis testing. The following section describes Nike's lean capability-building initiative and the opportunity it provided to test whether such interventions improve social performance in global production.

### 3. Lean Capability Building in the Nike Supply Chain

Facing supply chain challenges in delivery time, product quality, and workplace conditions, in the late 1990s, Nike began a search for management interventions for its supply base.<sup>3</sup> The Toyota Production System (Ohno 1988, Womack et al. 1991) was selected for emulation, and a Toyota consultant was hired to adapt lean concepts to footwear manufacturing. In 2002, Nike secured commitments from long-term footwear suppliers to implement the lean management and production system it had developed, and a dedicated training center was established in 2004 to train both factory managers and Nike staff. By May 2011, 80% of Nike's footwear suppliers had committed to adopting the new system.

Lean concepts have been widely studied and applied without a clear consensus on the definition of lean production (Shah and Ward 2007). In this study, we characterize the Nike production system as "lean" by reference to common goals and features in lean systems described by key works in the literature. The features of the Nike system (described in Table 1) included

identifying the core value stream and orienting production around this concept; balancing production processes using takt time (i.e., the available time for production divided by consumer demand); eliminating waste through the reduction of inventory buffers and works in progress; increasing operator participation in quality control and problem solving for continuous improvement; and improving operational stability with 5S, standardized work, and visual management techniques (Womack and Jones 1996, MacDuffie 1995, Shah and Ward 2003).

Nike reported business performance gains associated with its lean intervention in footwear, including increased productivity, reduced defect rates, and reduced lead times for both delivery and the introduction of new models (Nike, Inc. 2012). If these practices improved productivity and quality, why did manufacturers require outside intervention to adopt them? In fact, management practices associated with inferior organizational performance are relatively widespread even in advanced industrial economies (Bloom and Van Reenen 2007). The adoption of new management practices is not fully explained by superiority in efficiency. It is instead constrained by prevailing intellectual dispositions, preexisting assumptions about human behavior, institutional conformity, and asymmetries between visible costs versus hard-to-measure benefits (Guillén 1994, Pfeffer 2007). Implementing modern management systems like lean also requires knowledge that may be difficult to acquire in developing countries (Bloom et al. 2013). For these reasons, supply chain capability building is neither unusual nor unique to Nike. Its lean program resembles well-known initiatives to develop supplier capabilities by Toyota, Honda, and other automakers (Sako 2004).

The perceived success of the footwear program led Nike to expand the lean program to its apparel supply chain, which is the subject of our study. The global apparel industry employs tens of millions of workers in the developing world (International Labour Organization 2005) and has traditionally offered opportunities for developing countries to integrate with global production networks (Gereffi 1999). As of November 2015, Nike contracted with 396 apparel factories across 40 countries, employing over 370,000 workers.<sup>4</sup>

The first wave of lean adopters came from Nike's Apparel Manufacturing Leadership Forum, a group of strategic manufacturing partners with long-term relationships to Nike. Subsequent waves of lean-adopters were nominated by Nike Apparel Liaison Office directors. Senior management from invited suppliers were initially brought to the footwear training center in Vietnam and introduced to the Nike lean production system. All invitees accepted Nike's offer to receive training and agreed to implement the system in their own plants. In general, the factories receiving the

**Table 1.** Minimum Definitions of Nike Lean Production System (Apparel Manufacturing)

1. Connect or link at least one process to the core value stream	Before lean, almost all apparel factories had physically disconnected sewing, ironing, and packing, with high inventory buffers between each process. Connecting processes to the core value stream (sewing, in apparel factories) means physically moving operators and machines into the line, with process cycle time balanced to the line takt time. In practice, most apparel factories chose to connect ironing and packing at the end of each sewing line.
2. Control inventory via flow racks, kanbans, and pull systems	Flow racks allow for easy retrieval of inventory on a first-in-first-out basis; kanbans are cards used to signal the start and end of production. Both tools support pull systems, which drive production by demand at the end of the process and reduce waste by eliminating inventory that would ordinarily build up in the value stream to absorb variability in production processes.
3. Utilize an Andon system to signal problems in the line	The Andon system allows production team members to quickly signal production problems to the entire team. Suppliers must adopt a visual system (e.g., colored flag, card, or digital signboard) to signal problems, such as production defects, machine malfunctions, or an operator's need for relief. Depending on the problem, activating the Andon may temporarily stop production while the problem is addressed.
4. Track appropriate metrics for safety, quality, delivery, and cost	The minimum definition requires collection of these key performance indicators. Suppliers are expected to use these measures to track their performance and drive improvements in the value stream.
5. Use in-station quality inspection	The concept of not accepting, making, or passing on a defect is introduced to the line. Operators are asked to self-inspect their own output rather than depend on end-of-line inspection.
6. Utilize standard work in the core value stream	Standardized work involves specifying standards for the rate of production (takt time), required inventory, and sequence of operator actions. These are written on worksheets located at each work station.
7. Show evidence of 5S and visual management	5S (sorting, setting, shining, standardizing, and sustaining) ensures operational stability by eliminating waste from the work environment. Sorting removes nonessential tools and materials from the workspace. Setting arranges the workers, parts, and materials to minimize waste as value-added tasks are performed. Shining maintains the cleanliness of the workstation and its usability by subsequent operators. Standardizing and sustaining refer to the institutionalization of these practices. Visual management techniques include signs, shadow boards, tape to mark walkways and production areas, and colors to indicate performance.
8. Manage the core value stream as a single entity rather than individual processes	Before lean adoption, each production process was managed by separate supervisors. Once ironing and packing are connected to the end of sewing lines, a single supervisor would be responsible for all processes in that line and the final output.

*Note.* Nike personnel certified lean production lines in apparel factories by evaluating the adoption of these eight practices.

intervention were larger plants with preexisting sourcing relationships to Nike.<sup>5</sup>

The first group of apparel suppliers committed to the Nike lean program in 2007 and began meeting to discuss lean concepts and receive limited training. A full training curriculum was offered starting in 2009 at the newly opened Apparel Innovation and Training Center in Sri Lanka. The program trained supplier managers to oversee the lean transformation of their factories. The training program worked on a self-funding model that involved significant commitment from suppliers. Participating factories sent managers to the Sri Lanka training center for eight weeks and paid tuition to cover program costs.<sup>6</sup> The training center was located inside an active apparel supplier, which allowed trainees to observe and to practice what they learned in a lean manufacturing environment. After completing the program, trainees worked with a Nike manager to develop a rollout strategy for their home factories. They began by establishing a pilot line and pursuing one element of the transformation, adding new elements until all were adopted and stabilized.

After suppliers completed this reorganization of production lines, Nike personnel visited the plant to observe progress and to certify that the lines possessed the core elements of lean production. Their minimum

definition of “lean” covered eight features, summarized in Table 1. The production line must connect or link at least one process to the core value stream; control inventory via flow racks, kanbans, and pull systems; use an Andon system to signal problems in the line; track appropriate metrics for safety, quality, delivery, and cost; use in-station quality inspection; use standardized work; show evidence of 5S and visual management; and manage the core value stream as a single entity rather than individual processes. In addition to these criteria, Nike personnel also looked for managerial understanding of these processes and the use of takt time and cycle time to organize production. These practices include key elements of the Toyota Production System (Monden 2012, Womack et al. 1991) and many that appear in studies of modern manufacturing management, including techniques of inventory control, processes to support quality improvement, and the collection and analysis of performance indicators (Bloom et al. 2013, Bloom and Van Reenen 2007).

### 3.1. Hypothesized Mechanisms Linking Lean to Social Performance

The intervention described in Table 1 primarily sought to transform the organization of production, rather than to raise workplace labor, health, and environmental standards. Although lean manufacturing

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emphasizes the importance of trust and respect in the workplace (Monden 2012), Nike's lean program did not train suppliers on meeting social standards nor raise social performance demands beyond those applied to other suppliers. Nonetheless, there are theoretical reasons to expect that lean manufacturing may lead to improved factory social performance. Drawing on previous research we posit two such mechanisms, one stemming from changes in labor relations and the other from new management systems.

The first hypothesized mechanism involves increased employee involvement and its effect on labor relations. Lean manufacturing systems, including Nike's, include elements of high-involvement work: workers possess increased skills and knowledge, the opportunity to use those skills and knowledge, and the motivation to do so (Bailey et al. 2001). Lean involves more decentralized decision making, giving workers responsibility for a wider range of tasks than in traditional mass production<sup>7</sup> (Appelbaum 2000, MacDuffie 1995). Workers in lean systems integrate quality inspection into production work, suggest process improvements, and are more likely to engage in multiple production operations (Berg et al. 1996, Dunlop and Weil 1996). In the Nike system, workers were trained to conduct in-station quality inspection and to communicate problems to supervisors and coworkers. They were also trained to halt production upon discovering major quality problems. Workers also became responsible for cleaning and arranging their workstations according to the 5S demands. These were significant new responsibilities in comparison to the routinized tasks of traditional mass production.

Increased levels of worker involvement may lead to improved workplace standards through two channels. First, motivating discretionary effort is key to unlocking the performance benefits of high-involvement work systems (MacDuffie 1995, Becker and Huselid 1998, Appelbaum 2000). Whereas individual efficiency under traditional mass production can be incentivized through piece-rate compensation, in high-involvement work systems, "[w]orkers will only contribute their discretionary effort to problem-solving if they believe that their individual interests are aligned with those of the company, and that the company will make a reciprocal investment in their well-being" (MacDuffie 1995, p. 201). This may involve raising incentives to reward performance either individually or collectively (e.g., based on the quality or on-time delivery performance of the entire line). Alternatively, managers may pay an efficiency wage premium to motivate difficult-to-observe dimensions of employee effort (Appelbaum 2000, Bailey et al. 2001). Second, high-involvement work requires increased firm investments in employee human capital. High-involvement work systems require production workers to acquire

skills that were not required in traditional mass production, including both technical and interpersonal skills (Cappelli and Rogovsky 1994). Firm-led employee training programs are therefore a key element of high-involvement work systems (MacDuffie 1995, Ichniowski et al. 1997, Becker and Huselid 1998). Increased need for training in high-involvement work systems increases the costs of worker turnover; the more employers invest in workers, the more costly it is when workers leave the firm (Cappelli and Rogovsky 1994, MacDuffie 1995). Thus, managers may improve terms of employment in order to improve employee retention, a major challenge in many emerging market manufacturers.

The key empirical prediction of the labor relations mechanism—whether it passes through the need to motivate discretionary effort or to retain skilled employees—is an increase in wages and nonwage benefits. In addition, other working conditions that influence worker motivation and satisfaction may improve as well, such as total work hours, noise and temperature on the shop floor, and sanitation in worker dormitories. Consistent with these predictions, several studies of U.S. firms show that high-involvement work systems are associated with increased employee compensation (Appelbaum 2000, Bailey et al. 2001, Cappelli and Neumark 2001, Osterman 2006). The labor relations mechanism holds that lean will raise labor standards for similar reasons.

An alternative mechanism is that management systems associated with lean manufacturing reduce the marginal cost of complying with certain labor, health, and environmental standards (King and Lenox 2001), even if labor relations remain largely unchanged. In addition to changes to workers' role in production, lean emphasizes the development of process improvement capabilities (Womack et al. 1991). These modern management techniques are not widely diffused in emerging markets (Bloom and Van Reenen 2007). If noncompliance with certain workplace standards is the result of flawed management processes, lean may provide the tools to correct those processes to ensure compliance. Examples include the absence of processes to appropriately label and store hazardous chemicals or ineffective inventory management that leads to obstruction of emergency exits. Improved production planning and reduced cycle time (Dunlop and Weil 1996, Appelbaum 2000) may also reduce pressure on worker overtime to meet delivery deadlines (Locke et al. 2009). By introducing improved systems of process improvement, industrial hygiene, and production planning, lean may reduce the costs of remediating these violations of workplace standards. Consistent with this account, previous research on U.S. firms finds that the adoption of lean manufacturing is associated

with improved environmental performance (King and Lenox 2001).

The labor relations and management systems hypotheses are not mutually exclusive; both may be at work. However, they offer divergent predictions about lean's effects on factory social performance. If increased worker involvement necessitates efficiency wages or raises the costs of turnover, we expect improvement in social performance standards that directly influence employee motivation and well-being, such as wages and nonwage benefits. In theory, workers might be sensitive to workplace health and safety standards as well. However, we assume that wages and benefits are generally more influential in determining worker motivation and job satisfaction. Survey evidence from migrant workers in China finds that they are more than twice as likely to report "low pay" (80%) as "poor working conditions" (35%) when reporting why they intend to leave a job (Smyth et al. 2009). On the other hand, if lean's effects on social performance are primarily due to new management systems, we expect to see the largest effects in technical standards, such as industrial hygiene, hazardous substances, and emergency egress.<sup>8</sup> After estimating the effect of lean on labor standards, we shed light on these mechanisms by examining the detailed workplace practices associated with Nike's compliance grades.

To our knowledge, this is the first study to estimate the effects of lean on workplace standards across a large sample of emerging market manufacturers. Innovative case study research offered initial support for lean's effect on labor standards in emerging markets (Locke et al. 2007a), but a small sample size raised the possibility that these effects were idiosyncratic to particular factories or local labor markets. Moreover, other research suggests that the move toward lean production in global supply chains has harmed labor standards in emerging markets. In 2003–2004, Oxfam International led a research project on the supply chain practices of 20 companies spanning 15 countries. On the basis of interviews with factory and farm workers, managers, government officials, union and NGO representatives, trading agents, importers, and staff from major brands and retailers, it concluded that "...current sourcing strategies designed to meet 'just-in-time' delivery (premised on flexibility and fast turnaround), combined with the lowering of unit costs, are significantly contributing to the use of exploitative employment practices by suppliers" (Dhanarajan 2005, p. 531). According to this study, lean production is mimicked rather than genuinely practiced when suppliers do not possess the capabilities to cope with demands by global buyers for shorter production lead times, a greater diversity of products and styles, and lower unit prices. They conclude that "As a result, it is most definitely the workers at the labor-intensive stage

of production who are getting leaned on" (Raworth and Kidder 2009, p. 170). A study by the Clean Clothes Campaign of 30 garment factories in Sri Lanka, Bangladesh, India, and Thailand found that demands by large retailers like Walmart, Carrefour, and Tesco for quick turnaround and lower unit costs were undermining the ability of suppliers to comply with codes of conduct (Clean Clothes Campaign 2008). Finally, field research in a footwear factory in China found that lean manufacturing increased health and safety risks for workers (Brown and O'Rourke 2007). In light of these conflicting claims, it remains unclear whether lean manufacturing is part of the problem or part of the solution.

#### 4. Data and Empirical Strategy

Measuring workplace compliance with social standards is challenging even in advanced economies (Weil 2008). Upstream suppliers in today's global supply chains are predominantly located in emerging economies, where workplace inspectorates may be understaffed, lack critical technology for managing data, or both (International Labour Organization 2011). We address these challenges by measuring factory social performance with audits that assess compliance with Nike's supplier code of conduct. These audits use common inspection procedures and standards across factories in a range of developing countries. This permits for repeated observations of compliance with social standards in several hundred factories that would otherwise be difficult for researchers to access.<sup>9</sup>

Nike evaluates factory compliance with standards in labor, health, and environmental performance using periodic factory audits. Supplier factories are audited for social compliance every 12 to 18 months, according to a schedule that takes into account their previous compliance ratings and levels of factory risk. Adoption of lean manufacturing does not factor into this priority calculation, and there is no scheduling coordination between the operational teams responsible for lean manufacturing and compliance auditing.

One-third to one-half of these audits are conducted by Nike compliance personnel, a team of approximately 70 employees. Nike's in-house auditors have technical expertise in human resource management, engineering, and health and safety. The remaining audits are performed by third-party auditors. Third-party audit vendors are trained by Nike and subjected to annual reviews to ensure that their auditing procedures and grades align with Nike's in-house team.<sup>10</sup> Factories that fail to reach a minimum B grade within a defined timeframe have been required to pay for their own third-party audits since June 2012. The purpose of the dual system is to allow higher-performing factories access to the Nike compliance personnel who can facilitate improvements beyond the minimum compliance



standard. A factory’s progress in lean is not used when making decisions about audit scheduling or the use of third-party versus internal auditors.

Nike divides its factory compliance program into two topic areas monitored through two different factory audits: health, safety, and environment (HSE) and labor.<sup>11</sup> In both, findings are based on auditor inspection of conditions in factory buildings, interviews with workers and managers, and review of legal documents, timesheets, and wage records. These audits summarize factory compliance using a four-point scale: A (4) to D (1). A description of the scoring rubrics is reprinted in the appendix (see Table A.4). In labor compliance, factories that score A or B demonstrate no serious violations of the standards. The key difference is that A factories have fewer than five uncorrected minor issues, and B factories have more than five minor issues to address. In labor compliance, factories rated C exhibit at least one “serious” violation of the code. These include failure to provide basic terms of employment, more than 10% of employees working between 60 and 72 hours each week, and isolated instances of underage labor, verbal harassment, or failure to provide minimum legal wage or benefits. Factories rated D exhibit “critical” violations of the labor code, including denial of auditor access and provision of false information, unapproved outsourcing to other factories, use of forced labor, systemic use of underage labor, pregnancy testing as a condition of employment, failure to accurately record work hours, and more than 10% of employees exceeding daily work hour limits. The grading rubric for HSE compliance follows a similar pattern, with factories rated A or B being largely compliant and demonstrating progress, and factories rated C or D exhibiting serious system failures and failing to show improvement. In this study, noncompliant grades refer to audits resulting in Cs or Ds. We analyze the relationship between these compliance grades and individual workplace practices after presenting our main results.<sup>12</sup>

We built a panel of factory labor and HSE compliance ratings over time (Table 2). These data consist of factory audit results from FY2009 to the first half of FY2014. (The Nike fiscal year starts in June and ends in May.) Because the lean-adopting factories are all apparel manufacturers, our sample includes only apparel factories in the same 11 countries as the lean adopters. When factories are not audited in a given half-year period, we impute factories’ compliance scores using the results of their most recent audit. We consider the imputation of missing values preferable to the assumption that data are missing at random. Although we can test whether missingness is correlated with our indicator for lean adoption, we cannot verify the assumption that missingness is uncorrelated with potential social performance outcomes. We also

**Table 2.** Factory Compliance Panel Summary

	Labor		HSE	
	No	Yes	No	Yes
Imputed values?	No	Yes	No	Yes
Countries	11	11	11	11
Factories	300	300	332	332
Observations	862	2,704	959	2,504
Compliance scores (%)				
A (4)	19.3	16.7	0.1	0.2
B (3)	39.9	45.0	42.6	44.4
C (2)	26.0	24.3	53.6	51.9
D (1)	14.8	14.0	3.6	3.5
Observations by country (%)				
Bangladesh	3.5	2.8	2.8	2.5
Cambodia	0.2	0.4	1.7	1.6
China	47.4	43.3	43.1	42.9
Egypt	0.6	0.7	0.8	0.9
India	7.0	6.6	5.3	5.3
Indonesia	7.5	8.7	8.2	8.1
Malaysia	7.9	8.7	8.1	7.8
Sri Lanka	6.5	7.5	5.0	5.3
Thailand	12.2	11.9	11.6	10.9
Turkey	2.6	3.4	3.0	3.9
Vietnam	4.6	5.8	10.3	10.9

*Notes.* Summary statistics for the factory compliance panels in labor and in health, safety, and environment (HSE), showing pre and postimputation of missing values. Missing values are imputed by using start point imputation, carrying over each factory’s most recent compliance score from preceding periods. Our panels include only factories with at least two audits over the time period. Because Nike uses separate audits for labor and HSE, the samples are not identical.

have reason to believe that labor, health, and environmental conditions in factories exhibit considerable inertia. These workplace practices are tied to management routines, the local labor market, and the priorities of factory leadership. Empirical evidence suggests that factories’ most recent compliance scores are informative of their state between audits. Analyzing consecutive audits within factories, we find that factories retain identical compliance scores in 73% of consecutive labor audits and 84% of consecutive HSE audits. Only in 8% of labor audits and 1% of HSE audits do factories change by more than one grade. We therefore believe that imputing missing values is the empirical approach least likely to introduce bias, because it retains information from the entire sample of factories in each time period. However, we also repeat our main analysis with no imputation of missing data with no change in findings. The larger number of imputed values for labor compliance results from the larger number of labor scores available early in the panel. Approximately one-half of the factories are located in China, and one-third are in Southeast Asia. Noncompliant factories (rated C or D) comprise over one-third of our labor panel and one-half of our HSE panel.

As of FY2014, factories that adopted lean production exhibited better labor and HSE compliance than nonadopters. Lean adopters had a mean labor grade of 3.14, compared to 2.63 among nonadopters

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**Table 3.** Lean Adoption in the Compliance Panel

Year	Labor sample		HSE sample	
	Factories	%	Factories	%
FY2009	0	0	0	0
FY2010	12	4	12	4
FY2011	27	9	27	8
FY2012	53	18	56	17
FY2013	60	20	64	19
FY2014	64	21	68	20

*Note.* The table displays the count of lean-adopting factories in the panels and their share of all factories at the start of each fiscal year.

( $p$ -value < 0.01). For HSE, they averaged 2.79 compared to 2.36 among nonadopters ( $p$ -value < 0.01).<sup>13</sup> These differences lend initial support to the idea that lean production is associated with better social compliance. However, this cross-sectional comparison cannot rule out the possibility that lean adopters possess unobserved characteristics that explain their higher levels of social performance.

We use the panel data structure and the gradual introduction of lean manufacturing across the supply base to address concerns about unobserved confounding factors. Table 3 describes the progress of lean adoption in the factory panels. Although no factory had adopted lean at the beginning of the sample period in FY2009, approximately 20% of factories had implemented lean before the end of our sample period in FY2014. This progressive proliferation of lean manufacturing allows us to control for both time-invariant factors associated with each factory and time-varying compliance shocks to the entire pool of factories. We estimate lean’s effect on social compliance using a standard two-way fixed-effects regression model given by

$$Y_{it} = \eta_i + \delta_t + \alpha \text{Lean}_{it} + \varepsilon_{it}. \quad (1)$$

In this equation,  $Y_{it}$  is the compliance score on a four-point scale from A (4) to D (1),  $\eta_i$  is a factory fixed effect that controls for time-invariant unobserved confounding factors,  $\delta_t$  is a half-year fixed effect to control for common shocks across the pool of factories,  $\text{Lean}_{it}$  is our measure of lean adoption, and  $\varepsilon_{it}$  is an error term with  $E[\varepsilon | \eta, \delta, \text{Lean}] = 0$ . The parameter of interest is  $\alpha$ , the effect of adopting lean production techniques on compliance scores. Under the assumption of parallel counterfactual trends in the treatment and control groups, the average treatment effect on the treated is identified by within-factory change in compliance scores among factories that adopt lean production. This strategy improves upon cross-sectional comparisons by eliminating concerns about time-invariant and slow-changing differences between lean adopters and nonadopters, such as factory location, product focus, business culture, size, ownership, and levels of managerial competence prior to lean adoption. Although

the four point compliance score is an ordinal variable, we estimate these models using ordinary least squares (OLS) rather than ordered probit or logit. The maximum likelihood estimator is inconsistent in the presence of fixed effects (Greene 2004), and OLS provides the best linear approximation to the conditional expectation function (Angrist and Pischke 2008). Below we also conduct robustness checks that use dichotomized versions of the compliance grades. All estimations cluster standard errors at the factory level to account for potential serial correlation and heteroscedasticity.

For robustness we use two measures of lean adoption at the factory level. The first, lean adoption, is a binary indicator of whether a factory has any certified lean production lines at the start of a given time period. The certification of production lines represents the major qualitative shift toward new management systems; it is the result of months of manager training, numerous changes to production processes, and retraining of involved workers. Our second measure captures the intensity of the lean treatment by measuring the share of total production lines certified to Nike’s minimum lean standard; it varies continuously from 0 to 1. Because we use lean certification by Nike staff to measure the intervention, our treatment variables are likely somewhat lagged. By the time that production lines are certified by Nike personnel, supplier factories have already undergone an extended process of training and production line modifications. Nonetheless, lean certification provides a useful metric because it is measured against a uniform standard by Nike lean staff. The treatment is also slightly lagged by our coding of lean adoption according to the state of the factory on the first day of a time period, which ensures that lean adoption in our data predates the factory audit. Neither our lean measures nor our social compliance scores rely upon factory self-reporting, which may be subject to biases motivated by self-interest.

#### 4.1. Selection Bias

Because the lean intervention was not randomly assigned to factories, we must consider whether the selection process that led to lean adoption biases our estimates of  $\alpha$ . The key concern with selection bias in difference-in-differences models is within-unit variation in unobserved characteristics that correlates with within-unit variation in the treatment. For selection into the lean program to bias our results—either through Nike’s decision about whom to invite or suppliers’ decisions whether to participate—factory adoption of lean must correlate with changes in unobserved characteristics that also affect social performance.

As described in §3, factories were invited by Nike to receive training that ultimately led to adoption of lean manufacturing techniques. Their criteria for selecting

invitees included the length of Nike's business relationship with the supplier, factory size, and the perceived commitment of supplier leadership to engage with Nike's lean program. These qualities might be expected to produce higher levels of social performance among the invitees, which limits the credibility of cross-sectional comparisons between lean adopters and nonadopters for estimating the effect of lean. Our model is identified by within-factory variation in lean adoption over time rather than cross-sectional differences between plants. We investigated the possibility that Nike's invitation to join the lean program was correlated with other within-factory changes that might directly affect factory social performance and confound our estimates. Specifically, we researched possible changes in auditing frequency (were lean adopters audited more often?), auditing criteria (did the presence of lean lines influence auditors' evaluations?), and access to training (did lean adopters receive additional training on social compliance?). According to a review of internal documents and interviews with Nike management, lean adoption did not produce changes in these aspects of their relationship to suppliers. A second possible concern is whether factories' decisions to accept Nike's training invitation correlated with their ability to demonstrate improvement in social performance, but no suppliers declined the invitation to receive lean training.

We empirically explore threats to inference in three ways. We test whether changes in auditing frequency confound estimates of lean's effect. We also examine

whether unobserved labor market trends across countries may have influenced Nike's decisions about which factories to invite, thereby introducing bias. Finally, we examine the assumption of parallel trends among lean adopters and nonadopters in the pretreatment period. Consistent with the parallel trends assumption, we find no evidence of divergent trends until after lean adoption.

## 5. Results

Table 4 presents the main results of our estimation using two measures of lean adoption. Odd-numbered models use the binary indicator of lean adoption, and even-numbered models use the continuous measure: the percentage of lean-certified production lines in a plant. In both specifications, lean manufacturing has a positive effect on labor compliance. The adoption of any lean lines results in an improvement of 0.29 letter grades, 11% of the dependent variable mean (Model 1). Going from zero lean lines to a 100% lean factory is associated with an improvement of over half a letter grade (Model 2). We estimate a small positive effect of lean adoption on HSE compliance on the four-point scale, but the coefficients are imprecisely estimated.<sup>14</sup> We also test whether these results are driven by our approach to missing data by comparing estimates from both imputed (balanced) and nonimputed (imbalanced) panel data. Lean's estimated effect on labor compliance is larger in the imbalanced panels (Models 3 and 4), but statistical comparisons fail to detect significant differences in effects across alternative approaches to missing data.

**Table 4.** Effects of Lean Manufacturing on Compliance Scores

Dependent variable:	<i>Labor compliance</i>				<i>HSE compliance</i>			
	Yes		No		Yes		No	
Imputed values:								
Mean score (no lean):	2.58		2.56		2.35		2.33	
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Lean adoption</i>	0.29** (0.11)		0.42** (0.14)		0.08 (0.07)		0.05 (0.09)	
% lean lines		0.57** (0.16)		0.77** (0.21)		0.08 (0.11)		0.03 (0.15)
Factory FEs	✓	✓	✓	✓	✓	✓	✓	✓
Half-year FEs	✓	✓	✓	✓	✓	✓	✓	✓
Effect magnitudes (% of dependent variable mean)								
Point estimate (%)	11	22	16	30	4	3	2	1
95% CI upper (%)	20	34	27	46	9	12	10	13
95% CI lower (%)	3	10	6	14	-2	-6	-5	-11
Factories	300	300	300	300	332	332	332	332
Total observations	2,704	2,704	862	862	2,504	2,504	959	959

*Notes.* The table shows OLS panel fixed-effects regression from FY2009 H1 to FY2014 H1. Models are fit using both start point imputation of missing data and no imputation of missing data. Regression coefficients are shown with robust standard errors clustered by factory in parentheses. The outcomes are factory compliance grades on a four-point scale (A = 4, B = 3, C = 2, D = 1) for labor and for health, safety, and environment (HSE). The two codings of the independent variable are any lean adoption (1 if the factory has adopted any lean lines, 0 otherwise) and percentage of lean lines (count of lean lines/total lines in factory). Effect magnitudes are expressed in percent of mean compliance scores for all nonlean factory-half observations. CI, confidence interval.

\*\* $p < 0.01$ .

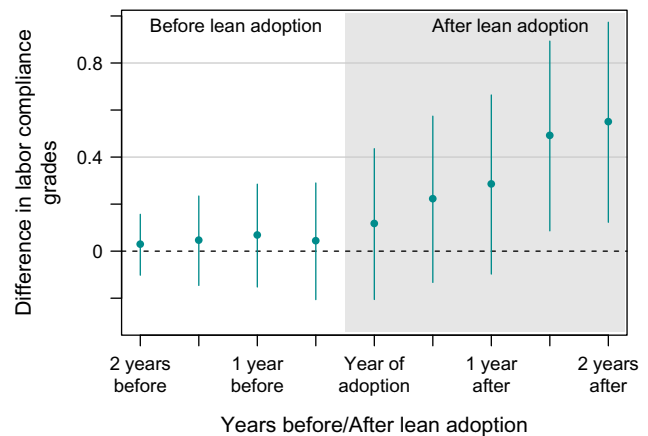
One potential concern with the preceding analysis is the validity of the parallel trends assumption, which implies that average outcomes for lean adopters and nonadopters would follow parallel trends in the absence of the intervention. To inspect differences in treatment and control groups before and after the intervention, we estimate a panel model using leads and lags of the treatment, similar to that in Autor (2003). We recode our treatment indicator as the “switch” from the last time period of no lean lines to the first time period with any lean lines. We then add binary leads and lags of this indicator to the model. The coefficients on these indicators estimate the differences between lean adopters and nonadopters at periods just before and after the adoption of lean in the treatment group.

$$Y_{it} = \eta_i + \delta_t + \sum_{a=-4}^4 \beta_a \text{leanswitch}_{i(t-a)} + \varepsilon_{it}. \quad (2)$$

Our fixed effects remain the same as the ordinary panel model. The explanatory variable  $\text{leanswitch}_{it}$  is a binary indicator that takes the value 1 only if factory  $i$  certifies its first lean production line in period  $t$ . The four leads and lags of this indicator take the value 1 only when factory  $i$  certifies its first lean line in the time period  $(t - a)$ . For nonadopters, these indicators always take the value 0. The result is a model with nine explanatory variables corresponding to the switching period and four leads and lags of that switch. By estimating coefficients for these leads and lags ( $\beta_a$ ), this specification allows us to inspect differences between lean-adopting plants and nonadopters before and after they certify their first lean lines. If unmodeled differences in compliance trends between the treatment and control groups are driving our results, we may observe differences in labor compliance between adopters and nonadopters before the introduction of lean manufacturing. Apart from providing this check of the parallel trends assumption, this model also allows us to examine how the effect of lean emerges over time.

Figure 1 plots the estimated coefficients for these indicators, including 95% confidence intervals, highlighting the periods before and after lean adoption. We detect no significant placebo effects in the two years before lean adoption, which suggests that unmodeled differences between adopters and nonadopters did not significantly affect labor compliance and therefore the parallel trends assumption seems plausible. We would not expect to see parallel pretreatment trends if lean adopters were cherry-picked based on recent improvements in social performance. The figure also illustrates variation over time in the effect of the intervention. The improvement in labor compliance grows consistently in the years following lean adoption, reaching a statistically significant level 18 months after adoption. Two years after certifying their first lean line, lean plants on

Figure 1. (Color online) Leads and Lags of Lean Adoption



Notes. The figure shows the results of estimating Equation (2). Estimated effects of lean manufacturing on labor compliance in periods before (white area) and after (gray area) factory adoption of lean manufacturing are shown. Coefficients are displayed with 95% confidence intervals from panel regression using four leads and four lags of a lean adoption indicator (robust standard errors are clustered by factory). The period of adoption represents the first period in which the factory had any lean production lines on the first day of that period. The plot shows no significant differences in labor compliance between lean adopters and nonadopters before lean adoption, but adopters improve after switching to lean, with the difference reaching statistical significance 1.5 years after adoption. Results are based on 300 factories and 2,704 factory-half observations; full regression results are reported in Table A.2 in the appendix.

average score 0.63 letter grades higher on their labor audits than non adopters. In periods before lean certification, we observe statistically insignificant positive differences between adopters and nonadopters. These may be the result of the lagged nature of our treatment indicator. Our coding shows when Nike formally certified lean production lines, but not when factories initially adopted lean production practices. In some cases, factories adopted their first pilot lines two years before their first lean certification.

A second concern with the previous tests is that we treat the four-point letter grades as continuous variables, implicitly assuming that adjacent grades are equidistant from one another. In Table 5 we relax this assumption and replicate the analysis with binary transformations of the compliance scores. The first transformation codes A or B as 1, and C or D as 0. Recall that Cs and Ds respectively indicate “serious” and “critical” violations of labor standards, as detailed in Table A.4. The second transformation codes only A as 1 and all other scores as 0. We again use OLS rather than logit/probit because of the inconsistency of the maximum likelihood estimator in fixed-effects estimation (Greene 2004). Again, we find a significant positive effect of lean adoption on labor compliance, present in both transformations of the dependent variable. These specifications also highlight that the weak effect on HSE compliance is primarily in moving factories up to a B score. The effects reported in the first two columns

**Table 5.** Binary Transformations of Dependent Variables

Dependent variable (DV):	Labor compliance				HSE compliance			
	AB = 1, CD = 0		A = 1, BCD = 0		AB = 1, CD = 0		A = 1, BCD = 0	
DV coding								
DV mean (no lean):	0.59		0.14		0.39		0.003	
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Lean adoption</i>	0.15*		0.08		0.10		0.00	
	(0.07)		(0.05)		(0.06)		(0.00)	
% lean lines		0.28**		0.24**		0.12		0.01
		(0.11)		(0.08)		(0.10)		(0.01)
Factory FEs	✓	✓	✓	✓	✓	✓	✓	✓
Half-year FEs	✓	✓	✓	✓	✓	✓	✓	✓
Factories	300	300	300	300	332	332	332	332
Total observations	2,704	2,704	2,704	2,704	2,504	2,504	2,504	2,504

Notes. The table shows OLS panel fixed-effects regression from FY2009 H1 to FY2014 H1 (11 periods). Regression coefficients are shown with robust standard errors clustered by factory in parentheses. The outcomes are binary transformations of factory compliance scores for labor and for health, safety, and environment (HSE). The first transformation codes factories receiving A or B grades as 1, and 0 otherwise. The second transformation codes factories receiving only an A grade as 1, and 0 otherwise. The two codings of the independent variable are lean adoption (1 if the factory has adopted any lean lines, 0 otherwise) and percentage of lean lines (count of lean lines/total lines in factory).  
 \* $p < 0.05$ ; \*\* $p < 0.01$ .

of Table 5 are particularly important. As we explain below, the gap between compliant (A and B) and non-compliant (C and D) grades is largely a function of accurate payment of worker wages and benefits (see Figure 2). We estimate in column (1) that lean adoption reduces the probability of receiving a noncompliant grade by 15 percentage points.

Finally, we examine the possibility that improvements might be explained by increased auditing of the lean plants. Because audits identify noncompliant practices that factories are instructed to improve, they might stimulate improvements in working conditions. If lean adopters received more frequent compliance audits, their labor standards could improve because of the effect of auditing. We reestimate our models with indicators of the cumulative number of audits each factory has received and find no significant difference in the estimated effect of lean adoption (see Table A.1 in the appendix). This is consistent with previous research showing limited improvements in labor standards from repeated factory inspections (Locke 2013).

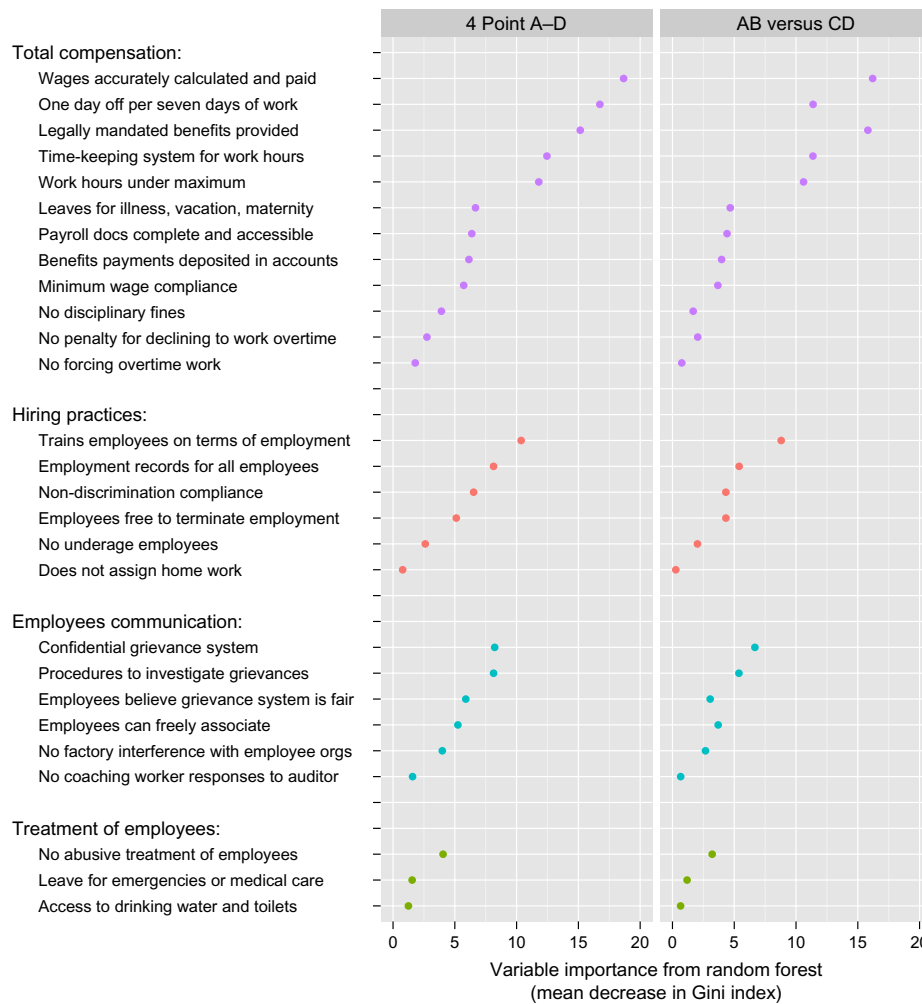
### 5.1. Mechanisms

Above we identified two mechanisms that may drive these results. The labor relations hypothesis held that increased demands on worker skill and discretionary effort incentivized managers to improve the terms of employment. In contrast, the management systems hypothesis focused on how lean changes the marginal costs of compliance from the managers' perspective. By developing capabilities surrounding process improvement, industrial hygiene, and production planning, lean may reduce the costs of complying with technical workplace standards. The labor relations hypothesis predicts improvement in terms of employment that

directly bear on workers' motivation and job satisfaction, such as wages and benefits. The management systems hypothesis predicts improvement in technical areas of compliance, such as hazardous materials and emergency egress.

Lean's effect is predominantly on labor standards rather than health, safety, and the environment (Table 4). The difference between point estimates for labor and HSE is statistically significant for the continuous measure of lean, but not the binary indicator of lean adoption. Because Nike's labor audit includes measures of wages and benefits, this offers preliminary support for the labor relations hypothesis. However, this depends on whether labor compliance grades are actually informative of terms of employment that are important to worker motivation and satisfaction. To shed light on this question, we analyze the relationship between labor compliance grades and detailed workplace practices. We merged compliance grades with records of detailed workplace practices for a subset of audits. This allows us to analyze the relationship between compliance grades and workplace practices for 442 audits.<sup>15</sup> We estimate the importance of 27 audit line items for predicting overall labor compliance scores using the random forest algorithm (Breiman 2001). Random forests are among the most popular techniques to emerge from the machine learning literature, in part because they offer extreme flexibility (Varian 2014). They do not require parametric assumptions on the functional form relating predictors to outcomes and can accommodate a range of nonlinearities and interactions that are difficult for researchers to specify when faced with a large number of predictors. In evaluating the relative contribution of over two dozen practices to the overall grade, we faced

Figure 2. (Color online) Predictors of Labor Compliance Grades



Notes. The figure shows random forest estimates of variable importance from sample of audits with detailed subscores for labor compliance, with a total of 442 audits over FY2008–FY2012. Variable importance is measured by the sum of all decreases in the Gini impurity index associated with splitting on a given variable, normalized by the number of trees in the forest (Breiman 2002, Liaw and Wiener 2002).

exactly this modeling challenge. We separately conducted analyses of the four-point compliance grade (A–D) and a dichotomized version: compliant grades (As and Bs) versus noncompliant grades (Cs and Ds). A similar analysis of HSE compliance grades appears in Figure A.1 in the appendix.

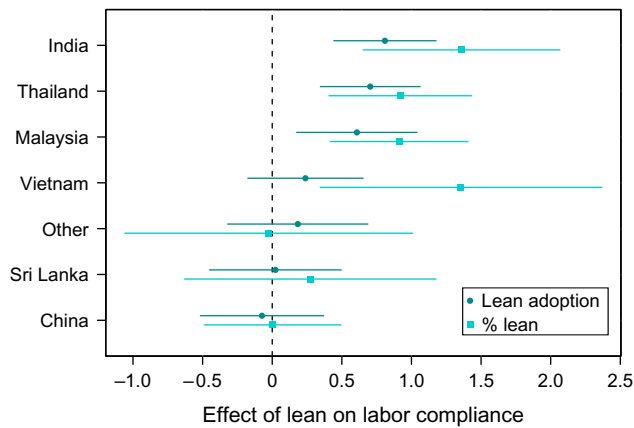
Consistent with the labor relations hypothesis, these results show that variation in labor compliance scores reflects important differences in employee compensation. Figure 2 plots variable importance scores for these workplace outcomes, which are grouped by category.<sup>16</sup> The most important workplace practices for predicting labor compliance grades are related to employee compensation and hours, especially accurate payment of wages, one day off per seven days of work, provision of legally mandated benefits, time-keeping for work hours, and keeping work hours under the maximum limit. In contrast, HSE grades, where we find no significant improvement, are primarily determined by technical and procedural standards that do not play

a major role in worker motivation and retention. The top predictors are risks from confined spaces and the management of hazardous substances (see Figure A.1). Although these are important working conditions, workers cite them significantly less often than wages as a reason for leaving the enterprise (Smyth et al. 2009).

## 5.2. Heterogeneous Effects by Country

Finally, we examine the effects of lean in different countries. We interact the lean measures in our panel model with country indicators to estimate country-specific treatment effects. The seven countries that occupy at least 5% of the sample each have their own indicators, and the remaining countries are pooled into a residual indicator comprising Bangladesh, Cambodia, Egypt, Indonesia, and Turkey.

We find significant heterogeneity in the treatment effect across countries (Figure 3). In India, Malaysia, and Thailand, any lean adoption is associated with

**Figure 3.** (Color online) Country-Specific Treatment Effects

*Notes.* The figure displays point estimates with 95% confidence intervals (using robust standard errors clustered by factory) from a fixed-effects model interacting country indicators with treatment variables. The two codings of the independent variable are lean adoption (1 if the factory has adopted any lean lines, 0 otherwise) and percentage of lean lines (count of lean lines/total lines in factory). Countries pooled in the “other” indicator are Bangladesh, Cambodia, Egypt, Indonesia, and Turkey. Results are based on 300 factories and 2,704 factory-half observations. Regression results are available in Table A.3 in the appendix.

improvement of over half a letter grade in labor compliance. The effect in Vietnam is smaller but statistically significant. However, in China, Sri Lanka, and our pool of residual countries, lean adopters do not improve significantly. *F*-tests reject the hypotheses that the effect in China is identical to those of India ( $p$ -value < 0.01), Thailand ( $p$ -value < 0.01), and Malaysia ( $p$ -value < 0.03). Although lean adoption appears to have a large effect on labor standards in several key apparel-exporting countries, we detect no effect on factories in China, where nearly half of our sample is located.

This country-level heterogeneity in effects raises the possibility that country-specific labor market or regulatory trends may be confounding our estimates of the effects of lean. Factories in countries experiencing wage increases or more stringent regulations may be more motivated to embrace process changes to maintain competitiveness. At the same time, those within-country labor market trends may exert their own effects on workplace standards. To address this possibility, we estimate models that allow for country-specific linear and quadratic time trends. These controls model the possibility that countries exhibit divergent trends in workplace compliance unrelated to the presence of lean manufacturing. The estimated effects of lean attenuate slightly but remain statistically indistinguishable from the main estimations (see Table A.1).

## 6. Discussion

Our findings support the hypothesis that lean manufacturing and associated high-involvement work

practices can improve social performance in emerging market manufacturers. Based on a five-year analysis of a capability-building intervention in the global apparel industry, we estimate that adoption of any lean manufacturing is associated with an improvement of 0.29 labor compliance grades, or a 15 percentage point increase in the probability of compliance (A or B grades). Although this finding by no means obviates concerns about working conditions in emerging markets, it does provide the first quantitative evidence on the efficacy of capability building in improving labor standards in global supply chains.

These results are consistent with the hypothesis that lean changes labor relations in ways that stimulate improved workplace standards. Because lean requires increased investments in worker training and higher levels of discretionary effort, managers have an incentive to improve labor conditions in order to retain and motivate skilled employees. We find that the top predictor of labor compliance grades is wage compliance, an improvement that is difficult to explain by improved techniques of process improvement, production planning, or industrial hygiene. At the same time, these two mechanisms are not mutually exclusive, and we cannot exclude the hypothesis that management systems also play a role. It is also important to consider that compliance with some health, safety, and environment standards may require structural changes to the plant, such as constructing new fire exits, changing wiring, or investing in pollution mitigation equipment. Such changes may be more costly and slow changing than adopting new practices in worker hiring, compensation, and hours.

Future quantitative and qualitative research may clarify the relative contributions of the labor relations and management systems mechanisms. One empirical approach would involve estimating lean’s effect on more narrowly defined workplace outcomes whose improvements are attributable to one mechanism but not the other. Taking Nike’s compliance subscores as an example, improvements in wages, verbal abuse by supervisors, disciplinary fines, and worker grievance systems seem unlikely to be explained entirely by improved management systems. On the other hand, standards dealing with wastewater management and fire safety precautions appear unlikely to play a major role in worker motivation and retention. Studying the effects of lean on these fine-grained workplace outcomes, including worker turnover rates, could shed light on causal mechanisms. Qualitative research on manufacturers negotiating changes in production systems would also be highly informative. Key intermediate outcomes—such as new kinds of worker training and new channels of communication between workers and management under the labor relations

hypothesis—may be obvious from focused examination of individual workplaces but challenging to quantify for a large sample of factories in the absence of panel surveys of employees and managers.

The effect of lean on labor standards was strongest in India, Malaysia, Thailand, and Vietnam. However, we detect no effect of the lean intervention in Sri Lanka, China, and the pool of remaining countries. It is perhaps unsurprising to find little improvement in Sri Lanka, a country known for high levels of factory social compliance (Ruwanpura and Wrigley 2011). Among factories in Sri Lanka, 85% of nonlean observations exhibited a labor compliance rating of B or higher, with 31% receiving A ratings. The same cannot be said for China, where just 57% of nonlean observations received a B or higher, and only 8% received an A grade. China's labor compliance grades are comparable to factories in India (48% B or higher, 10% As), where factories exhibited significant improvement.

One clue to the absence of an effect in China is the lower intensity of lean adoption. By the start of FY2014, all 12 Thai lean adopters, 9 of 10 in Malaysia, and all 3 in India had certified more than 33% of their production lines to meet Nike's minimum definition. In contrast, 6 of the 16 lean adopters in China had less than 33% lean lines. If the effects of lean are associated with a certain threshold level of adoption, then perhaps factories in China have not yet reached that threshold.

A second possibility is that features of China's industrial workplace create barriers to the development of high-involvement work systems that devolve meaningful decisions to workers. Previous research on lean and high-performance work systems emphasizes the importance of complementary "bundles" of work and personnel practices in delivering benefits for the firm (Milgrom and Roberts 1990, MacDuffie 1995, Dunlop and Weil 1996). If changes in labor relations are the primary mechanism through which lean affects labor standards, key elements of the bundle may include institutions that facilitate communication between workers and management and foster the necessary trust to give workers meaningful decision-making authority. Contemporary China has highly limited institutions of worker voice, with the official labor union failing to provide significant bottom-up representation of worker interests and opposing higher levels of worker participation in decision-making (Friedman and Lee 2010, Brown and O'Rourke 2007). In the absence of institutions facilitating voice and trust, employers may adopt the physical and managerial elements of lean without implementing the high-involvement work practices that stimulate improved labor standards.

Learning more about mechanisms and heterogeneous effects across workplaces is the focus of our future research. Regardless of the mechanisms that

produce positive spillovers for social performance, lean capability building differs in fundamental ways from the traditional private regulatory approach to social responsibility in supply chains. The dominant mode of private regulation attempts to improve workplace conditions through the threat of external sanction. Buyers mandate that suppliers meet social responsibility standards in order to do business. For the sanction-based system to work, the buyer has to be willing to bear the costs of adequately financing an auditing team to monitor compliance as well as switching costs associated with terminating relationships with noncompliant suppliers. In turn, the supplier must believe that investments in improved conditions are more valuable than losing the buyer's business. However, the last decade of research offers evidence that these programs offer limited improvements, because buyers continue business relationships even under conditions of sustained noncompliance (Barrientos and Smith 2007, Egels-Zandén 2007, Lund-Thomsen et al. 2012, Locke 2013, Distelhorst et al. 2014). Even when traditional compliance regimes function as designed, the buyer must continuously apply these pressures, with their associated costs for all parties, to sustain improved workplace conditions. In contrast, previous research shows that lean and other forms of modern manufacturing deliver substantial benefits to business performance (Ichniowski et al. 1996, Bloom et al. 2013). If these practices can be successfully introduced, suppliers themselves may have a stake in maintaining them.

How generalizable are our findings? The intervention we studied was firm driven and implemented in the naturalistic setting of actual manufacturers across 11 emerging markets. The manufacturing practices that comprise Nike's lean intervention (Table 1) are widely known and commonly employed in a range of manufacturing settings. Because these practices are not highly idiosyncratic or proprietary, our findings may be applicable to similar interventions by other firms. Our findings also come from an industry in which emerging markets play an important role. After China and the European Union, the world's biggest exporters of apparel are Bangladesh, Vietnam, India, and Turkey (World Trade Organization 2014). With low barriers to entry, apparel manufacturing is viewed as a "starter" industry for growth strategies that emphasize export-oriented industrialization (Gereffi 1999). In these ways, our findings on lean manufacturing and labor standards are theoretically applicable to firms across a variety of emerging markets.

At the same time, there are important limits to generalizability. As a model for improving social compliance in global supply chains, capability-building interventions may be limited to large buyers like Nike. Large multinationals have more resources to support training programs, and the scale of their orders makes



it easier to persuade suppliers to invest in implementing new management systems. This intervention also targeted suppliers with long-term business relationships with Nike. If such relationships are a precondition for intensive collaboration on management systems, this intervention may not be plausible in supply chains with high supplier turnover. In short, we should neither over- nor undergeneralize from the results of this research. Lean manufacturing is associated with improved labor standards in this important case, but it would be prudent to replicate these analyses with new industries and lead firms.

One important limitation of this study is our limited data on the features of individual factories and their sourcing relationships to Nike. It may be instructive in future research to explore the effects of lean manufacturing on buyer order volume and, more generally, on the relationship between buyers and suppliers. Capability building programs may produce higher levels of trust and relational contracting in the buyer–supplier relationship. A common complaint from developing world suppliers is that buyers demand improvements in factory labor conditions but lack commitment to continued sourcing (Ruwanpura and Wrigley 2011, Locke et al. 2009). Suppliers' belief that customer relationships are fragile and short-lived reduces incentives to invest in social compliance. In the Nike case, capability building targeted suppliers that already enjoyed long-term sourcing relationships with Nike. However, in other cases, capability building may credibly signal commitment to an extended sourcing relationship,

thereby increasing supplier trust that investments in social performance will not go to waste.

Our findings have straightforward implications for multinational management practice. Capability building diverges from traditional private regulation in its attempt to create value for both the buyer and supplier, such that both parties have incentive to cultivate and sustain new management practices. By offering evidence that certain forms of capability building enhance factory social performance, we identify a specific opportunity to create “shared value” in global supply chains (Porter and Kramer 2006). If global buyers, supplier management, and the production workforce simultaneously derive benefit from this approach to manufacturing, lean capability building may represent a form of self-enforcing institutional change that supports improved working conditions in emerging markets.

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## Appendix

**Table A.1.** Effects of Lean, Controlling for Cumulative Compliance Audits and Country Trends

Dependent variable:	<i>Labor compliance</i>						<i>HSE compliance</i>					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
<i>Lean adoption</i>	0.29** (0.11)	0.29** (0.11)	0.21 (0.11)				0.08 (0.07)	0.04 (0.07)	0.00 (0.06)			
<i>% lean lines</i>				0.57** (0.16)	0.57** (0.16)	0.44** (0.15)				0.08 (0.11)	0.00 (0.11)	0.04 (0.10)
<i>Cumulative audits</i>		0.10 (0.13)	0.04 (0.13)		0.10 (0.13)	0.04 (0.13)						
<i>(Squared)</i>		−0.01 (0.03)	0.01 (0.03)		−0.01 (0.03)	0.01 (0.03)						
Country time trends			✓			✓			✓			✓
Factory FEs	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Half-year FEs	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Factories	300	300	300	300	300	300	332	332	332	332	332	332
Total observations	2,704	2,704	2,704	2,704	2,704	2,704	2,504	2,504	2,504	2,504	2,504	2,504

*Notes.* Alternative specifications of the compliance models estimated in Table 4 are shown, controlling for cumulative audits and country-specific time trends (linear and quadratic) for each of the 11 countries in the sample. Cumulative audits are the total number of audits the factory has experienced as of the current period. The outcomes are factory compliance grades on a four-point scale (A = 4, B = 3, C = 2, D = 1) for labor and for health, safety, and environment (HSE). The two codings of the independent variable are any lean adoption (1 if the factory has adopted any lean lines, 0 otherwise) and percentage of lean lines (count of lean lines/total lines in factory).

\*\* $p < 0.01$ .

**Table A.2.** Effects of Leads and Lags of Lean Adoption on Labor Compliance

Dependent variable:	Labor compliance
Model:	(1)
<i>leanswitch</i> <sub><i>t</i>+4</sub>	0.0272 (0.0658)
<i>leanswitch</i> <sub><i>t</i>+3</sub>	0.0443 (0.0966)
<i>leanswitch</i> <sub><i>t</i>+2</sub>	0.0662 (0.111)
<i>leanswitch</i> <sub><i>t</i>+1</sub>	0.0419 (0.126)
<i>leanswitch</i> <sub><i>t</i></sub>	0.115 (0.163)
<i>leanswitch</i> <sub><i>t</i>-1</sub>	0.220 (0.180)
<i>leanswitch</i> <sub><i>t</i>-2</sub>	0.283 (0.193)
<i>leanswitch</i> <sub><i>t</i>-3</sub>	0.490** (0.205)
<i>leanswitch</i> <sub><i>t</i>-4</sub>	0.548** (0.216)
Factory FEs	✓
Half-year FEs	✓
Factories	300
Total observations	2,704

*Notes.* The table shows OLS panel fixed effects regression from FY2009 H1 to FY2014 H1. Regression coefficients are shown with robust standard errors clustered by factory in parentheses. The outcomes are factory labor compliance grades on a four-point scale (A = 4, B = 3, C = 2, D = 1). The binary indicator *leanswitch*<sub>*t*</sub> takes the value 1 only in the first period after lean adoption. The leads and lags of this indicator allow us to examine differences between the treatment and control groups before (*t* + *a*) and after (*t* - *a*) lean adoption. The results are plotted in Figure 1.

\**p* < 0.05; \*\**p* < 0.01.

**Table A.3.** Country-Specific Effects of Lean on Labor Compliance

	(1)	(2)
<i>Lean adoption</i>		
× <i>China</i>	-0.074 (0.225)	
× <i>Thailand</i>	0.704** (0.182)	
× <i>Vietnam</i>	0.239 (0.211)	
× <i>Sri Lanka</i>	-0.023 (0.240)	
× <i>Malaysia</i>	0.608** (0.220)	
× <i>India</i>	0.809** (0.187)	
× <i>Other</i>	0.184 (0.256)	
<i>Percent lean lines</i>		
× <i>China</i>		0.003 (0.249)
× <i>Thailand</i>		0.920** (0.260)

**Table A.3.** (Continued)

	(1)	(2)
<i>Percent lean lines</i>		
× Vietnam		1.355* (0.514)
× Sri Lanka		0.274 (0.459)
× Malaysia		0.912** (0.251)
× India		1.360 (0.359)
× Other		−0.025 (0.525)
Factory FEs	✓	✓
Half-year FEs	✓	✓
Factories	300	300
Total observations	2,704	2,704

*Notes.* The table shows OLS panel fixed effects regression from FY2009 H1 to FY2014 H1. Regression coefficients are shown with robust standard errors clustered by factory in parentheses. The outcomes are factory labor compliance grades on a four-point scale (A = 4, B = 3, C = 2, D = 1). The two codings of our lean measure have been interacted with country indicators to estimate treatment effects within each country that represents at least 5% of our sample. Bangladesh, Cambodia, Egypt, Indonesia, and Turkey make up the “Other” category. Results are plotted in Figure 3.

\*\* $p < 0.01$ .

**Table A.4.** Nike Compliance Audit Scoring Rubric

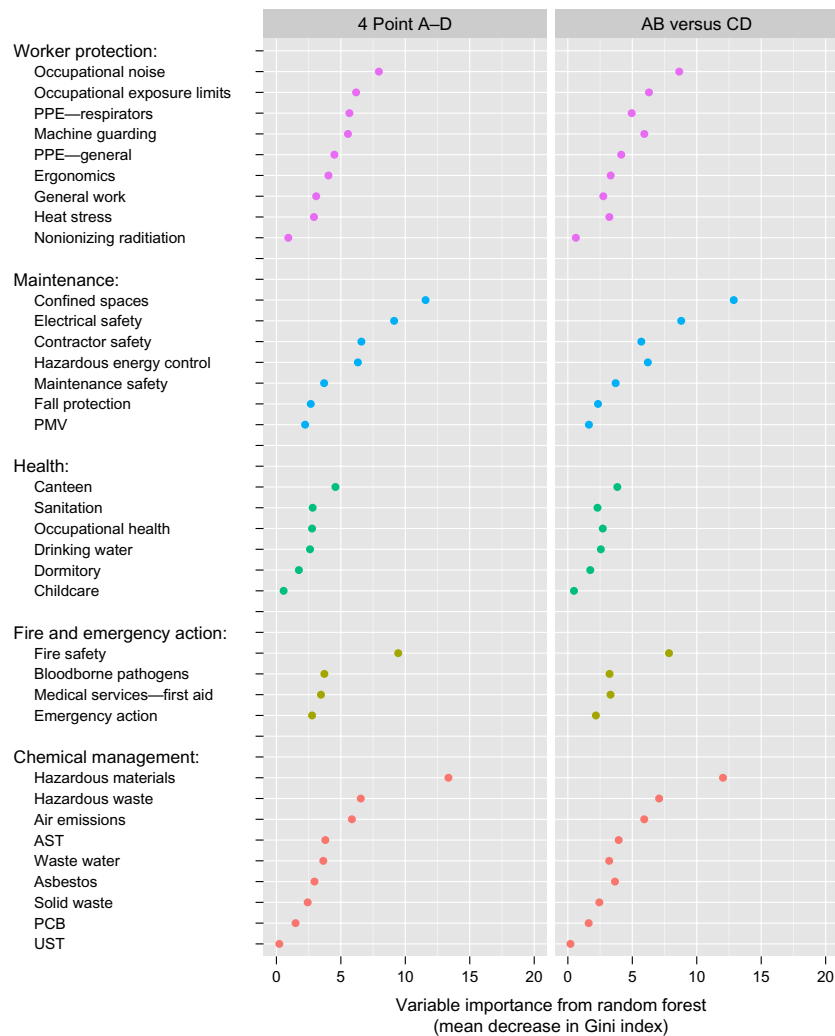
Grade	Labor	Health, safety, and environment
A	<ul style="list-style-type: none"> <li>Isolated violations of standards that do not rise to the level of “Serious” or “Critical” issues</li> <li>No more than five minor issues awaiting remediation</li> </ul>	<ul style="list-style-type: none"> <li>Fully compliant</li> <li>Demonstrates best practices</li> <li>Considered a leader</li> </ul>
B	<ul style="list-style-type: none"> <li>Isolated violations of standards that do not rise to the level of “Serious” or “Critical” issues</li> <li>More than five minor issues awaiting remediation</li> </ul>	<ul style="list-style-type: none"> <li>Mostly compliant</li> <li>Minor system failures</li> <li>Factory making progress</li> </ul>
C	<ul style="list-style-type: none"> <li>Factory not providing basic terms of employment (contracts, documented training on terms of employment, equal pay, discriminatory employment screening)</li> <li>Isolated use of workers under the minimum legal age or above the minimum legal age but under the minimum age of Nike’s standards</li> <li>Factory fails to honor a material term of a signed collective bargaining agreement</li> <li>Isolated case of not paying the legally mandated minimum wage; not providing legally required nonincome-related benefits; or failure to provide required income-related benefits</li> <li>Isolated verbal or mental harassment or abuse</li> <li>Violation of local laws regarding the use of migrant labor</li> <li>Serious violation of hours of work standard: factory fails to provide verifiable timekeeping system to accurately record work hours; more than 10% of employees work between 60 and 72 hours each week or work seven or more consecutive days without a break</li> </ul>	<ul style="list-style-type: none"> <li>Noncompliant</li> <li>Serious system failures</li> <li>Factory making no progress</li> </ul>
D	<ul style="list-style-type: none"> <li>Management specifically refuses or continues to demonstrate that it is not willing to comply with Nike Standards</li> <li>Any denial of access to authorized compliance inspectors</li> <li>Management provides false information (statements or documents or demonstrates coaching)</li> <li>Factory outsources to an unapproved or unauthorized facility or issues home work to employees</li> </ul>	<ul style="list-style-type: none"> <li>Noncompliant</li> <li>Demonstrates general disregard for Nike codes and standards</li> </ul>

Table A.4. (Continued)

Grade	Labor	Health, safety, and environment
D	<ul style="list-style-type: none"> <li>• Any use of bonded, indentured, or prison labor</li> <li>• Use of force to compel illegal work hours</li> <li>• Systemic use of workers under the minimum legal age for work</li> <li>• Factory denies workers freedom of association</li> <li>• Systematically not paying the legally mandated minimum wage or not providing legally required income-related benefits</li> <li>• Factory conducts pregnancy testing as a condition of employment</li> <li>• Systematically not providing legally required maternity leave</li> <li>• A confirmed serious incident of physical or sexual abuse or systemic harassment and abuse and/or failure to timely respond to complaint(s)</li> <li>• Critical violation of hours of work standard: lack of verifiable timekeeping system results in workers not having hours or work accurately recorded; more than 10% of employees exceed daily work hour limits, work more than 72 hours each week, or work 14 or more consecutive days without a break</li> </ul>	<ul style="list-style-type: none"> <li>• Unwilling or unable to drive important change</li> <li>• Deliberately misleads auditors</li> <li>• Audit shows critical systemic and widespread problems</li> </ul>

Note. See Nike, Inc. (2014) for more detail on the standards that these grades refer to.

Figure A.1. (Color online) Predictors of Health, Safety, and Environment (HSE) Compliance Grades



Notes. Random forest estimates of variable importance from sample of 313 audits with detailed subscores for HSE compliance. Includes factories from the eleven countries used in the main study. Variable importance is measured by the sum of all decreases in the Gini impurity index associated with splitting on a given variable, normalized by the number of trees in the forest (Breiman 2002, Liaw and Wiener 2002). PPE, personal protective equipment; PMV, powered motor vehicle; AST, above-ground storage tank; PCB, polychlorinated biphenyl; UST, underground storage tank.

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## Endnotes

<sup>1</sup> The most valuable apparel brands ranked by Millward Brown Opti-mor (2013) are Zara, Nike, H&M, Ralph Lauren, Adidas, Uniqlo, Next, Lululemon, Hugo Boss, and Calvin Klein. All have adopted supply chain social compliance programs, which are detailed in their corporate citizenship reports.

<sup>2</sup> “Noncompliant” grades are those in which auditors detected “Serious” or “Critical” violations of labor, health, or environmental standards, as opposed to “Minor” violations. In the Nike factory audit scoring rubric (see Table A.4 in the appendix), these are represented as C or D grades. More detail on factory social performance data appears in §4.

<sup>3</sup> The following description of Nike’s lean manufacturing program for apparel is based on internal documents provided by management and interviews and written correspondence with eight Nike managers over 2011–2014: four directors in lean manufacturing; one vice president, one director, and one development associate in sustainability; and one director in communications.

<sup>4</sup> For more detail, see Nike’s global manufacturing map: <http://manufacturingmap.nikeinc.com> (accessed February 21, 2016).

<sup>5</sup> These selection criteria are one reason why cross-sectional comparisons of social compliance outcomes do not produce credible estimates of lean’s effects on social outcomes. Previous research on working conditions among Nike’s suppliers found that strategic partners were more likely to have higher compliance scores (Locke et al. 2007a). We illustrate the problem with cross-sectional estimations below after reporting the results of our difference-in-differences analysis.

<sup>6</sup> The lean training program for apparel suppliers lasted 12 weeks, but managers returned from the Sri Lanka training center to their home factories during the middle 4 weeks to work on assignments.

<sup>7</sup> Traditional apparel manufacturing is commonly referred to as the “progressive bundle system,” an application of the principles of scientific management to clothing production. Garment production is decomposed into simple operations (e.g., individual seams), and workers specialize in performing one operation. To accommodate differences in worker speed, bundles of work-in-progress inventory buffer each step of production. It yields high levels of labor efficiency and machine utilization, but large inventory buffers also result in long cycle times. A garment that requires just a few minutes of actual labor may take several days to complete the process (Dunlop and Weil 1996, Appelbaum 2000).

<sup>8</sup> Both mechanisms predict improvement in overtime compliance. Reduction of excessive overtime may be the result of efforts to please employees by reducing the intensity of work or reduced cycle times and improved production planning.

<sup>9</sup> Nike, Inc., provided audit results for its apparel suppliers from FY2009 through the first half of FY2014, as well as internal documents describing its lean program. Nike also made key managers involved in its lean program available for multiple interviews with researchers. We agreed to withhold the names of individual suppliers as proprietary information in publications but were not otherwise constrained in our presentation of research outcomes.

<sup>10</sup> We tested for systematic differences in the labor audits conducted by Nike and third-party auditors. Comparing mean audit scores for a subsample of labor audits in the 11 countries studied, we find no significant difference in compliance grades. Using the four-point grading scale described below, the average grade assigned by third-party auditors was 2.35, and that assigned by Nike’s in-house auditors was 2.42, which yields a *t*-test *p*-value of 0.74. A chi-squared test of independence fails to detect differences in the compliance grade distributions across auditor types (*p*-value of 0.79).

<sup>11</sup> See Nike, Inc. (2014) for full documentation of these standards.

<sup>12</sup> It is important to note that the specific content of these social compliance standards varies according to local law. For example, the

minimum wage in China is different from the minimum wage in Vietnam. Our empirical approach accounts for this in part by focusing on within-factory differences in compliance over time. However, a necessary assumption is that these within-factory changes in grades are equivalent across factories.

<sup>13</sup> Nike compliance grades run on a four-point scale from D (1) to A (4). We examine compliance scores for apparel factories in Asia, Europe, the Middle East, and Africa as of FY2014 Q1. For labor compliance, we report audit data for 64 lean adopters and 236 non-adopters. In HSE compliance, we report 68 adopters and 264 non-adopters. *p*-values are reported from two-sided *t*-tests assuming unequal variances.

<sup>14</sup> We would have come to apparently erroneous conclusions about lean’s effects on HSE compliance if we had relied on estimates using cross-sectional variation. Examining compliance outcomes in our sample in FY2014, two-sided *t*-tests allowing for unequal variances estimate significant effects of lean adoption on both labor compliance (+0.51 grades,  $\sigma = 0.13$ ) and HSE compliance (+0.44 grades,  $\sigma = 0.06$ ).

<sup>15</sup> Ideally we would estimate the effects of lean on each workplace practice, but our data include just 16 prelean and 34 postlean observations of the treatment group.

<sup>16</sup> Variable importance scores summarize the predictive power of variables in classification trees, which do not yield coefficients in the same way as traditional regression models. Importance scores measure the total decrease in node impurities from splitting on a given variable, averaged over all trees. Node impurity is measured by the Gini index (Liaw and Wiener 2002).

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