Responsible Sourcing – Production Scale and Monitoring: Theory and Evidence

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Previous research has emphasized price incentives, certification, and monitoring as mechanisms to motivate suppliers to behave responsibly. We investigate another mechanism – the scale of production – and the tradeoff between scale and monitoring as mechanisms to induce responsible behavior. Our research encompasses both analytical modelling and empirical analysis. Theoretically, reducing the scale of production and monitoring are substitute mechanisms by which a brand can induce suppliers to behave responsibly. If monitoring is more costly, the brand should reduce both monitoring and production scale. To test the insights from the model, we collect and analyze data from Nike contract factories in China between 2013 and 2016. Consistent with the theory, workforce size (representing scale) is negatively correlated with distance from regional hubs averaged by number of factories (representing monitoring cost). Further, the negative relation between production scale and monitoring cost is positively moderated by the rule of law. The managerial implication is that scale matters in responsible sourcing – to a degree that increases with monitoring cost, moderated by the rule of law. The implication for local government policy is that improving transportation attracts foreign export orders by reducing monitoring costs, and enhancing the rule of law helps to mitigate high monitoring costs.

Key words: Production scale, social responsibility, supply chain incentives

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1. Introduction

In products ranging from low-tech (apparel and footwear) to high-tech (smartphones and laser printers), international outsourcing of production is ubiquitous. However, contract suppliers may evade social and environmental responsibility, or laws and regulations. To save costs, they may compel workers to work excessive hours, employ child labor, use unsafe facilities, or pollute the air and waterways.

Since the 1990s, Nike, the world's leading manufacturer of athletic footwear, has been intensely scrutinized for poor working conditions and employment practices at contract factories (Nisen 2013; Kish 2016). International brands of sweets such as Kit Kat and M&M have been implicated in sourcing cocoa produced by child labor in the Ivory Coast and Ghana (O'Keefe 2016). The collapse of Rana Plaza in Bangladesh, which killed over a thousand workers, cast an unfavorable spotlight on the manufacturing of Benetton, Mango, and Walmart branded apparel (Al-Mahmood et al. 2013). Similarly, Apple has been criticized for air and water pollution by its contract manufacturers in China (Hook and Hille 2011).

Enforced overtime, employment of child labor, failure to ensure safe facilities, and air and water pollution are possibly illegal, definitely irresponsible, and at best, unethical. Such actions by suppliers hurt global brands through bad publicity and loss of goodwill (O'Keefe 2016; Al-Mahmood et al. 2013), loss of sales and earnings (Spar and Burns 2000), and possibly legal sanctions.

Previous research has considered price incentives, certification, and monitoring as mechanisms to induce suppliers to behave responsibly (e.g., Chen and Lee 2016; Cho et al. 2016; Plambeck and Taylor 2016). Fu et al. (2014) show that the vertical structure of production (integrated/outsourced) affects supplier behavior in a way that depends on the scale of production. Here, we focus on outsourced production and investigate the tradeoff between the scale of production (order quantity) and monitoring as mechanisms to induce responsible behavior.

Conventionally, manufacturing is assumed to exhibit economies of scale. So far, most research into responsible sourcing has abstracted from the scale of production (either explicitly or implicitly by normalizing the scale) and focused on other mechanisms to regulate suppliers (e.g., Caro et al. 2015; Guo et al. 2016; Orsdemir et al. 2016; Plambeck and Taylor 2016). Yet, increasing the scale of production may not only reduce the unit cost of production, but it may also amplify the returns to irresponsible behavior. Suppose, for example, that a factory can reduce the cost of production by 10 cents per unit by employing child labor. Then, child labor would increase total profit by 10 cents multiplied by the scale of production. Hence, the larger is the scale, the greater would be the incentive to use child labor. The corollary is that reducing the scale would decrease the incentive to employ child labor (Fu et al. 2014). This key insight is consistent with empirical research into Nike's supply chain (Locke et al. 2007) and motivates our interest in the scale of production as a mechanism to regulate suppliers.

Previous research (e.g., Chen and Lee 2016; Plambeck and Taylor 2016; Caro et al. 2015) emphasizes the use of monitoring to regulate supplier behavior. Here, we investigate how to combine monitoring with production scale as mechanisms to induce suppliers to behave more responsibly. We are particularly interested in how the balance between monitoring and production scale depends on two factors.

One factor is the cost of monitoring. The other is more subtle and motivated by industry emphasis that "government bodies enforcing rule of law" complement monitoring by the brand and external agencies (Nike Inc. 2015, p. 58). Indeed, Locke et al. (2007) find that Nike suppliers in countries with stronger rule of law comply better with the corporate Code of Conduct.

Before introducing our analysis, it is useful to clarify some nomenclature. Mookherjee and Png (1992) distinguish enforcement that is conditioned on reports by the regulated entity from enforcement that is not conditional on any report. Research into responsible sourcing variously describes inspections of suppliers as "audits" (Chen and Lee 2016; Plambeck and Taylor 2016; Caro et al. 2015) or "inspections" (Cho et al. 2016), or use both terms interchangeably (Locke et al. 2007). However, it not clear that enforcement is any way conditional on supplier reports (Locke et al. 2007; Nike Inc. 2015; Adidas Group 2015; PUMA SE 2016). By contrast, in accounting and tax compliance, "audits" refer to enforcement that is conditional on reports. To avoid confusion, we describe enforcement as "monitoring".

Our study combines both theoretical and empirical analysis. We develop a stylized model comprising one supplier and one buyer (brand). The brand offers a contract comprising a wholesale price per unit, production scale (order quantity), and monitoring rate. If the supplier accepts the contract, and is monitored by the brand, the supplier incurs a cost of remediation. The supplier can reduce the cost of production by evading legal and responsible practices to a degree that, for simplicity, we call "evasion". The supplier chooses evasion to maximize profit, which comprises the revenue from the brand (wholesale price multiplied by production scale), less the cost of production (which decreases in evasion), and less the expected cost of remediation (which increases in evasion). In turn, subject to the supplier's choice of evasion, the brand sets the wholesale price, production scale, and monitoring rate to maximize its profit. The brand's profit is the revenue from sales to consumers less the sourcing cost paid to the supplier, less the cost of monitoring, and less a penalty which increases in the supplier's evasion.

Our model shows that reducing the scale of production and monitoring are substitute mechanisms by which the brand can reduce the supplier's incentive for irresponsible behavior. Hence, if monitoring is more costly, the brand will reduce monitoring and also reduce the scale of production. Stronger rule of law has a nuanced effect on the equilibrium between the brand and supplier. It strengthens the effectiveness of monitoring, but also increases the expected cost of remediation, which raises the wholesale price.

To test the insights from the theory, we collect data from Nike covering production and employment at contract factories in China between 2013 and 2016. During this period, the number of factories dropped from 200 to 160, and the average factory employed 1,240 workers. We represent the scale of production at each factory by the size of its workforce, and the cost of monitoring by the distance of the factory from the nearest Nike regional hub (in Beijing, Shanghai, or Guangzhou), normalized by the number of factories in the prefecture.

We regress the workforce size on the cost of monitoring, as well as the interaction between monitoring cost and the rule of law. The estimates control for average wages, quality of infrastructure, product categories, brand, province, and years. Consistent with our theoretical proposition that scale and monitoring are substitutes, we find that workforce size (representing production scale) is negatively correlated with monitoring cost. Further, consistent with our theory that the rule of law has conflicting effects on workforce size, we find, empirically, that the main effect of the rule of law is not statistically different from zero. By contrast, the rule of law positively moderates the negative relationship between scale and monitoring cost. Our empirical results are robust to alternative measures of scale and rule of law, and sample. In addition, we rule out three alternative explanations for the negative correlation between scale and monitoring cost.

Our work contributes to the operations management (OM) literature and managerial strategy in several ways. We show theoretically and confirm empirically that reducing the scale of production and monitoring are substitute ways to encourage responsible sourcing. Further, we show that, when the cost of monitoring is higher, then brands should temper the scale of production at each factory so as to mitigate evasion. This implies spreading production over a larger number of factories.

Finally, stronger rule of law, which enhances the effectiveness of monitoring, affects the production scale in conflicting ways. In theory, the more effective monitoring should reduce evasion and lead brands to increase scale. However, the more effective monitoring raises the supplier's cost of remediation, which inflates the wholesale price, and so, leads brand to reduce scale. Empirically, we find that the rule of law has no direct effect on production scale, but positively moderates the negative relation between production scale and monitoring cost.

Our findings also provide useful guidance to local governments competing for export business. It is well known that exports and foreign direct investment depend on the costs of transportation and communication (Hausman et al. 2013). Here, we derive a more nuanced implication. The scale of production in each factory decreases with the cost of monitoring. This means that, if the cost of monitoring is high, foreign brands would spread orders over more factories, and possibly to other cities and regions. To attract larger export orders, local governments should improve transportation and communication. Another way is to enhance the rule of law as stronger rule of law moderates the negative impact of high monitoring costs.

2. Literature Review

Our work closely follows the nascent stream of research into managing social and environmental responsibility in the supply chain (Kitzmueller and Shimshack 2012; Lee and Tang 2017), and is more distantly related to research into management of product quality. Research into social and environmental responsibility investigates various mechanisms by which brands can regulate suppliers to comply with laws, regulations, and corporate codes of conducts, and generally, behave responsibly and ethically.

The obvious and most direct way to regulate supplier conduct is to stipulate the desired behavior and enforce accordingly (Locke et al. 2007; Nike Inc. 2015; Adidas Group 2015; PUMA SE 2016). Monitoring may be carried out by the brand itself or third parties such as ILO Better Work (an initiative of the International Labour Organization and International Finance Corporation) and the Fair Labor Association.

Considerable research has modeled the brand's optimal monitoring strategy under various conditions. Chen and Lee (2016) consider a setting where suppliers differ intrinsically in their propensity to engage in unethical behavior, and find that the optimal strategy combines monitoring with certification and contingency payments. In Plambeck and Taylor (2016), suppliers can evade the brand's monitoring by hiding information from auditors or through bribery. Conventional mechanisms – increasing monitoring and paying higher wholesale prices – might backfire and induce the supplier to behave less responsibly. Caro et al. (2015) consider a setting where two brands contract with the same supplier, and then compare strategies of independent monitoring (each brand inspects the supplier independently), shared monitoring (brands inspect independently but share the reports), and joint monitoring (brands conduct inspections jointly and share the cost).

Another issue is how the brand's disclosure policy affects monitoring by non-governmental organizations (NGOs). In Chen et al. (2015), the brand must decide the rate of monitoring, and whether to disclose the monitoring rate and supplier list to NGOs. Monitoring by the brand and NGOs can be substitutes: the more that the NGO monitors, the less that the brand spends on monitoring, and so, disclosure may induce suppliers to behave less rather than more responsibly. In Cho et al. (2016), the brand must decide the rate of monitoring, whether to disclose the monitoring rate, and set the wholesale price. Monitoring and pricing are strategic substitutes. If the cost of monitoring is low, the brand solely relies on monitoring rather than providing monetary incentives, and hence the supplier might behave less rather than more responsibly.

Besides monitoring and related disclosure, brands can also regulate supplier conduct through contingent payments (Chen and Lee 2016; Cho et al. 2016) and certification (Chen and Lee 2016). At the extreme, the brand might simply vertically integrate and directly control production (Fu et al. 2014; Orsdemir et al. 2016).

Most previous theoretical research abstracts from differences in scale of production or order quantity. Previous analyses either normalize the order quantity to one (Caro et al. 2015; Cho et al. 2016), assume it to be exogenous (Plambeck and Taylor 2016), or simply do not consider the order quantity (Chen and Lee 2016; Chen et al. 2015). Yet, a long and rich tradition of research into manufacturing emphasizes economies of scale in production (Pratten 1971; Cachon and Terwiesch 2013). Conventionally, economies of scale are due to some fixed cost of facilities or intellectual property. Here, we investigate how evasion of law, regulation, or responsibility might also give rise to economies of scale, and how monitoring and scale interact with each other.

The management of supplier responsibility shares some similarity with the management of supplier quality. In both issues, the brand seeks to regulate unobservable actions by suppliers, which is a classic moral hazard problem. Theoretical research into the management of supplier quality focuses on designing contracts using various instruments, including monitoring, certification, and contingent pricing. Hwang et al. (2006) compare mandatory certification and supplier appraisal, while Chen and Deng (2013) investigate the use of product certification to screen suppliers.

Like research on supplier responsibility, the research on supplier quality emphasizes monitoring. for example, Babich and Tang (2012) consider monitoring and deferred payments as ways to regulate suppliers. Many papers in this literature stream also abstract from the scale or order quantity as a way to regulate suppliers (e.g., Baiman et al. 2000, 2001; Balachandran and Radhakrishnan 2005; Hwang et al. 2006; Chao et al. 2009; Babich and Tang 2012).

By contrast with the substantial theoretical work, there has been relatively little empirical analysis of management of supplier responsibility. Locke et al. (2007) studied inspections of Nike contract factories between 2001 and 2005. Audit scores for compliance with the Nike Code of Conduct were higher among factories located in countries with stronger rule of law, and lower among factories with larger workforces. However, Locke et al. (2007) did not interpret either result, and indeed, described the second finding (larger factories receiving worse scores) as "counter-intuitive" (page 16).

In a survey of 334 corporate members of SCM World across 17 industries, Porteous et al. (2015) find that improvement in social and environmental responsibility is most strongly associated with the penalty of contract termination following warning, and three incentives, one of which is an increase in orders. However, they do not interpret these empirical relations. Distelhorst et al. (2017) study the Nike supply chain for apparel between 2009 and 2014. They find that contract factories that introduced lean manufacturing methods were more likely to comply with wage and working hour standards, but did not change health and safety practices.

3. Theory

3.1. Model

Our model is broadly motivated by guidelines for responsible sourcing recently published by the Organisation for Economic Co-operation and Development, the association of advanced economies (OECD 2017). Consider a sequential game between one brand (buyer) and one supplier in a two-tier supply chain for one product. For simplicity, let the brand be a monopoly, retail demand be certain, and the cost of retailing be zero. The brand offers the supplier a contract that comprises the unit wholesale price of the product, w, the scale of production (order quantity), Q, and the rate, $\mu \in [0,1]$, at which it monitors the supplier. Retail demand is deterministic (a function of the retail price), so the brand orders just enough to satisfy the demand and sells at price, $p(Q)$.

Given the brand's offer, the supplier will accept the contract if it generates a non-negative profit and, otherwise, rejects the contract. The supplier can reduce the cost of production by evading legal and responsible practices to a degree that, for simplicity, we call "evasion", represented by $x \in [0, 1]$.

The brand suffers a penalty, $\phi(x)$, where $\phi'(x) > 0$ and $\phi''(x) > 0$, for the supplier's evasion. The penalty possibly comprises loss of revenue, profit, or goodwill, and legal and administrative sanctions. The function, $\phi(x)$, can be interpreted as the product of the rate at which NGOs or other external parties monitor the supplier and a penalty function, either of which increases with and is convex in the supplier's evasion. Alternatively, the function, $\phi(x)$, can be interpreted as the outcome of a rational expectations equilibrium between stakeholders including consumers and the brand. Although they do not directly observe the supplier's evasion, stakeholders understand the strategic situation and rationally anticipate the supplier's choice of x.

The effectiveness of the brand's monitoring of the supplier depends on the rule of law, represented by the parameter, $\lambda \in (0, 1]$. Formally, the effective rate of monitoring is $\lambda\mu$. The cost to the brand of monitoring at rate, μ, is $k\mu \geq 0$.

The supplier earns revenue of wQ. Its cost of production is $[1 - x]C(Q)$, where $C(Q)$ satisfies $C'(Q) > 0$, and $C''(Q) \geq 0$. This set-up fits the motivating illustration: If the supplier can reduce the unit cost of production by 10 cents by using child labor, then the overall saving is 10 cents multiplied by the total peoduction quantity. The supplier independently decides the degree of evasion, x.

If the brand monitors and successfully detects evasion, it will compell the supplier to remediate the harm (for instance, compensate workers for excessive overtime, improve factory conditions, or remove contamination). The supplier's cost of remediation is $r(x) > 0$, where $r'(x) > 0$ and $r''(x) > 0$. (We exclude the possibility that the supplier might take actions to avoid the brand's monitoring (Plambeck and Taylor 2016).)

For simplicity, in the analysis below, we focus on interior solutions, $Q^* > 0$, $x^* < 1$, and $\mu^* < 1$. Nevertheless, the same results continue to apply in the cases of boundary solutions, $x^* = 1$ or $\mu^* = 1$, but with the propositions suitably modified to state *weakly* increasing or decreasing changes.

3.2. Equilibrium

Consider the supplier. Its profit is the revenue from sales to the brand, less the cost of production, and less the expected cost of remediation,

$$\pi = wQ - [1-x]C(Q) - \lambda\mu r(x). \tag{1}$$

The supplier will engage in production if and only if it earns non-negative profit, $\pi \geq 0$, which is its participation condition.

Given non-negative profit, and conditional on w, Q, and μ, the supplier chooses evasion, x. Differentiating (1), the first-order condition is

$$\frac{d\pi}{dx} = C(Q) - \frac{dr}{dx}\lambda\mu = 0. \tag{2}$$

Let the inverse function of dr/dx be $v(\cdot)$, so (2) simplifies to

$$x = v\left(\frac{C(Q)}{\lambda\mu}\right), \tag{3}$$

and so,

$$\frac{dx}{dQ} = \frac{1}{\lambda\mu}\; v'C'(Q), \tag{4}$$

and

$$\frac{dx}{d\mu} = -\frac{1}{\lambda\mu^2}\; v'C(Q). \tag{5}$$

Differentiating (2),

$$\frac{d^2\pi}{d^2x} = -r''(x)\lambda\mu < 0,$$

so, the supplier's profit function is concave in x. Hence, (3) characterizes the supplier's evasion, $x(w, Q, \mu)$, as a function of the wholesale price, scale of production, and the brand's monitoring.

PROPOSITION 1. *The supplier's degree of evasion, x, increases in the scale of production, Q, and decreases in the monitoring rate, μ, and the rule of law, λ.*

Referring to (1), the expected cost of remediation is a fixed cost that does not vary with the scale of production, Q, while the return to evasion increases with the scale. Hence, the larger is the scale of production, the more the supplier chooses to evade laws and regulations and social responsibility. By contrast, the cost of remediation does increase with the brand's monitoring and the rule of law, and so, the supplier's evasion decreases with monitoring and the rule of law.

Proposition 1 is related to earlier work by Fu et al. (2014), who investigate the effect of vertical integration on responsible sourcing. They show that the choice of vertical structure (between integration and outsourcing) depends on the scale of production, which amplifies the profit from evasion. However, their analysis does not consider monitoring or the rule of law.

The empirical study by Locke et al. (2007) of the compliance of Nike contract factories with the corporate Code of Conduct provides some support for Proposition 1. Table 1 of this paper extracts their Table 4, which reports regressions of scores that factories received when they were first subject to audit of management and working conditions (represented in our model by $1 - x$) on the country-level rule of law, workforce size, and number of environmental, safety and health inspections by Nike.

Consistent with our Proposition 1, the audit score is positively correlated with the rule of law. Factories located in countries with stronger rule of law complied more closely with Nike's Code of Conduct. The positive coefficient of the rule of law is robust to the inclusion of other factory characteristics and fixed effects for region (Americas, Europe-Middle East-Africa, North Asia, and South Asia).

Also consistent with our Proposition 1, the audit score is negatively correlated with the size of the workforce. Locke et al. (2007) described this result as "counter-intuitive" and speculated that smaller factories are easier to control and monitor than larger facilities. Our model suggests a starkly different interpretation: the scale of production amplifies the benefit from irresponsible behavior, and so, larger factories engage in worse behavior.

By contrast, Locke et al. (2007) find weak results on the effect of monitoring on audit performance. The coefficient of the number of environmental, safety and health inspections is positive but not statistically significant. The coefficient is marginally significant in the estimate including other factory characteristics and region fixed effects. This suggests that Nike monitoring policy might differ systematically by region in ways correlated to compliance with the Code of Conduct.

Next, we analyze the brand's choice of wholesale price, production scale, and monitoring given that the supplier independently chooses the degree of evasion. The brand's profit is the sum of revenues from consumers, less the wholesale cost, less the cost of monitoring the supplier, and less the penalty for the social harm. Formally,

$$\Pi = p(Q)Q - wQ - k\mu - \phi(x). \tag{6}$$

The brand maximizes Π subject to the supplier's participation and choice of evasion, (3).

To maximize profit, the brand should set the wholesale price, w, such that the supplier just breaks even, $\pi = 0$. Using (1), this means $wQ = [1-x]C(Q) + \lambda\mu r(x)$. Substituting in (6), the brand's profit simplifies to

$$\Pi = p(Q)Q - \big[[1-x]C(Q) + \lambda\mu r(x)\big] - k\mu - \phi(x). \tag{7}$$

Differentiating (7), the brand stipulates the scale of production according to

$$\frac{\partial \Pi}{\partial Q} = p'(Q)Q + p(Q) - [1-x]C'(Q) + C(Q)\frac{dx}{dQ} - \lambda\mu r'(x)\frac{dx}{dQ} - \phi'(x)\frac{dx}{dQ} = 0, \tag{8}$$

which simplifies to

$$p'(Q)Q + p(Q) = [1-x]C'(Q) + \{\lambda\mu r'(x) + \phi'(x) - C(Q)\}\,\frac{dx}{dQ}. \tag{9}$$

By (4), if the brand increases scale, the supplier increases evasion, $dx/dQ > 0$, and thereby raises the cost of remediation (and the wholesale price) by $\lambda\mu r'(x) \cdot dx/dQ$, and raises the penalty by $\phi'(x) \cdot dx/dQ$, but reduces the cost of production by $C(Q) \cdot dx/dQ$.

Differentiating (7), the brand chooses the rate of monitoring according to

$$\frac{\partial \Pi}{\partial \mu} = C(Q)\frac{dx}{d\mu} - \lambda r(x) - \lambda\mu r'(x)\frac{dx}{d\mu} - k - \phi'(x)\frac{dx}{d\mu} = 0, \tag{10}$$

which simplifies to

$$-[\lambda\mu r'(x)+\phi'(x)-C(Q)]\frac{dx}{d\mu}=k+\lambda r(x). \tag{11}$$

Referring to (11), the left-hand side represents the marginal benefit of monitoring and the right-hand side represents the marginal cost. For the brand, monitoring yields a marginal benefit by reducing evasion, $dx/d\mu<0$. The reduction in evasion changes the brand's profit by reducing the cost of remediation (benefiting the brand through a lower wholesale price) and penalty, but raising the cost of production. In an interior solution, the marginal profit from evasion,

$$-\lambda\mu r'(x)-\phi'(x)+C(Q)<0, \tag{12}$$

otherwise the left-hand side of (11) would be negative and not yield any solution.

The marginal cost of monitoring is rather subtle. It comprises a direct element, which is the unit cost of monitoring cost, k, and an indirect element. The indirect element is the increased cost of remediation (which raises the wholesale price) due to the higher probability of detecting evasion. At the profit maximum, the brand balances the marginal benefit against the marginal cost.

Next, we investigate the relation for the brand between the scale of production and monitoring. Referring to (11), the issue is how the production scale affects the: (i) brand's marginal profit from evasion; (ii) supplier's marginal reduction in evasion with respect to monitoring, $dx/d\mu$; and (iii) brand's marginal cost of monitoring. In Appendix A1, we show that, formally, the effect of scale on (i) and (iii) resolves to the sign of $\phi''(x)-\lambda r''(x)$, which is the difference in the rates at which the marginal penalty and marginal effective cost of remediation increase with evasion. The effect of scale on (ii) simplifies to a term whose sign depends on the shape of $r'(x)$. Generally, the balance of these effects could be positive or negative. Accordingly, whether larger scale increases or decreases the brand's marginal profit from monitoring, i.e., whether $\partial^2\Pi/\partial Q\partial\mu$ is positive or negative, is a priori ambiguous.

Despite the possibly conflicting effects, we can derive a clearcut prediction with two mild conditions on the shapes of the penalty and cost of remediation.

Assumption 1. *Assume that (a) the marginal penalty on the brand increases faster than the supplier's effective marginal cost of remediation, $\phi''(x) > \lambda r''(x)$ and (b) the cost of remediation is thrice differentiable with $r'''(x) \leq 0$.*

Assumption 1(a) is actually quite reasonable, as absent such a condition, the brand would prefer the supplier to maximize evasion, which does not seem realistic at all. Assumption 1(b) is not very restrictive, and, for instance, satisfied by any power function, $r(x) = x^\eta$, with $1 < \eta \leq 2$. Essentially, $\eta > 1$ implies that the cost of remediation is an order higher in evasion than the cost of production, $[1 - x]C(Q)$, so that evasion is subject to diminishing returns, while $\eta \leq 2$ ensures that the cost of remediation is small enough that the supplier will exploit economies of scale.

Then, the next result shows that Assumption 1 is sufficient for the brand to treat the scale of production and monitoring as complementary mechanisms by which to manage the supplier's evasion of legal liability and social responsibility.

Proposition 2. *For the brand, the scale of production and monitoring are complements,*

$$\frac{\partial^2 \Pi}{\partial \mu \partial Q} > 0. \tag{13}$$

We emphasize that Assumption 1 is sufficient but by no means necessary. For instance, we do not need $r'(\cdot)$ to be weakly concave. If $\phi''(\cdot) \approx 0$, our result will hold if $\phi(x) > \lambda r'(x)$ (brand's marginal penalty exceeds supplier's marginal cost of remediation) and $r'''(x) \leq 0$. By contrast, if $\phi''(\cdot)$ is sufficiently large, then it would outweigh the negative terms in the cross-partial derivative, $\partial^2 \Pi / \partial \mu \partial Q$ (see the proof of Proposition 2). This condition is relatively easy to interpret. For scale of production and monitoring to be complements, an increase in scale must increase the marginal profit from monitoring. By Proposition 1, an increase in scale leads the supplier to increase evasion. If the penalty is sufficiently convex in evasion, the increase in scale would raise the marginal profit from monitoring.

Our next result shows that, if the cost of monitoring is higher, the brand will reduce the monitoring rate and scale of production.

Proposition 3. *In equilibrium, the scale of production, Q^*, and the monitoring rate, μ^*, decrease with the cost of monitoring, k.*

The rule of law amplifies the effect of the brand's monitoring of the supplier. Specifically, the effective rate of monitoring, $\lambda\mu$, increases with the rule of law, λ. An interesting question for managerial strategy and public policy is how differences in the rule of law affect the equilibrium scale of production and relation between the scale and cost of monitoring.

To understand the effect of the rule of law on the equilibrium scale of production, partially differentiate (8) with respect to λ, and substitute dx/dQ from (4),

$$\frac{\partial^2 \Pi}{\partial \lambda \partial Q} = \left[\frac{\phi''(x)r'(x)}{r''(x)} + \phi'(x) + [C(Q) - \lambda\mu r'(x) - \phi'(x)]\frac{r'''(x)r'(x)}{(r''(x))^2} - C(Q)\right]\frac{C'(Q)}{r''(x)\lambda^2\mu}.$$

The first two terms are positive, and by (12), and since $r'''(x) \leq 0$, the third term is also positive. However, the last term which represents the the scale reduction due to higher wholesale cost, $-C(Q) < 0$. Therefore, the sign of $\partial^2\Pi/\partial\lambda\partial Q$ is a priori ambiguous.

Intuitively, with stronger rule of of law, monitoring is more effective, and hence the brand should increase monitoring, and also increase the scale of production since monitoring and scale are complementary. However, stronger rule of law also increases the supplier's cost of remediation, which means that the brand must raise the wholesale price to ensure that the supplier breaks even. The lower margin induces the brand to reduce the production scale. The net effect of the rule of law on the scale of production depends on the balance between these conflicting forces.

The inherent conflict between the two effects makes it challenging to derive simple and intuitive conditions for the net effect of the rule of law on the scale of production in a general setting. It is also challenging to prove the joint effect of the rule of law and monitoring on scale. To establish clear predictions, we assume that the penalty and cost of remediation are quadratic.

Proposition 4. *Suppose that $\phi(x) = \phi x^2$ and $r(x) = rx^2$, and $\phi > \lambda r$. Then, $d^3\Pi/d\lambda dk dQ > 0$, i.e., if the rule of law is stronger, the marginal effect of monitoring cost on scale will be positive.*

By Proposition 3, the scale of production decreases with the cost of monitoring. Proposition 4 shows that stronger rule of law positively moderates this effect. Equivalently, if the rule of law is stronger, then the negative effect of the monitoring cost on scale will be smaller in magnitude.

Proposition 4 provides sufficient conditions for the joint effect of the rule of law and monitoring on scale of production to be positive. However, even under those conditions, we cannot find an unambiguous result for the (main) effect of the rule of law on scale (please refer to the Remark in the Appendix A1). Apparently, the effect of the rule of law on scale is an empirical question.

4. Empirical Study: Nike

Above, our theoretical analysis shows that the scale of production and monitoring are complementary mechanisms to regulate a supplier's responsible production by a supplier. The brand should temper the scale of production, and so, reduce the supplier's incentive to evade law, regulation, and responsibility. The degree of tempering increases in the cost of monitoring, and the degree of tempering according to the cost of monitoring decreases in the rule of law. However, the theory is ambiguous on the (main) effect of stronger rule of law on production scale.

In the leading empirical study of responsible sourcing, Locke et al. (2007) find that, among Nike contract factories, compliance with the corporate code of conduct increased with national rule of law and decreased with workforce size. However, they found weak results with respect to the number of inspections. The weak results might possibly be due to the measure of the rule of law being rather coarse. Locke et al. (2007) used the rule of law at the national level, and since this does not vary much over time, they could not control for differences in monitoring policy across countries.

Here, we investigate the relation between monitoring and production scale, and the moderating effect of the rule of law, in the context of Nike contract factories at the sub-national level. By exploiting differences in the rule of law at the sub-national level, we can avoid confounds due to national differences in corporate monitoring policy.

Nike is the world's leading manufacturer of athletic footwear, with sales in the year 2016 more than 85 percent higher than the second largest manufacturer, Adidas.[1] Nike outsources all of its manufacturing to contract factories. Following protests against child labor and sweatshops in the 1990s, then-CEO Philip Knight publicly committed to improve working conditions and employment practices at contract factories (New York Times 1998).

Every Nike contract factory is required to comply with a Code of Conduct which governs worker rights and the working environment. The Code is enforced by a "combination of internal audits, external audits, independent audits, and investigations, alongside government bodies enforcing rule of law" (Nike Inc. 2015, p. 58). In 2014 and 2015, Nike contract factories were subject to 1,279 inspections by Nike's own staff as well as 70 inspections by ILO Better Work and the Fair Labor Association (Nike Inc. 2015, pp. 62-63).

Using the Internet Archive Wayback Machine of past Nike publications, we compiled records of employment and other characteristics at contract factories in China between 2013 and 2016. During that period, the number of factories decreased from 200 to 160.

We combine the Nike data with three sets of Chinese data. The first set of data represents the cost of monitoring. Following previous research in international management and economic geography (e.g., Fladmoe-Lindquist and Jacque 1995; Lin and Png 2003), we stipulate that the cost of monitoring increases with geographical distance. We measure the geographical distance of each factory from the closest of three regional hubs – Beijing, Shanghai, and Guangzhou. Nike's Greater China headquarters is located in Shanghai, central China, and the company has also set up sourcing offices in Beijing and Guangzhou, which are the largest cities in the north and south. Monitoring teams would likely be based in the three regional hubs and monitor multiple factories within close proximity in a single trip instead of making multiple trips.

This motivates our construct for the cost of monitoring – the geographic distance of the factory from the closest of three regional hubs divided by the number of factories in the prefecture.

[1] https://www.statista.com/statistics/278834/revenue-nike-adidas-puma-footwear-segment/

(Administratively, China is divided into provinces, further divided into prefectures, and further divided into counties.) We use the Stata routine, geodist, to calculate the distance between the closest of the regional hubs and the prefecture in which the factory is located.

The second set of data pertains to the rule of law. The effectiveness with which brands monitor suppliers depends on the rule of law at the local level (Nike Inc. 2015, p. 58). As defined by the World Bank, "[r]ule of law captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence."[2]

The China Market Index (Wang et al. 2017) publishes two relevant indexes – the legal environment of business and protection of intellectual property rights – by province every two years. The legal environment index is based on surveys of firms' evaluation on the justice and efficiency of the local judiciary and administrative organs. The intellectual property rights index is based on granted patents. Our construct for the rule of law is the average of the two indexes. In robustness tests, we also apply each index separately.

The last dataset comprises average wages and the density of paved roads, both at prefecture level from yearbooks published by National Bureau of Statistics of China, Department of Urban and Social Economic Survey. Factory workforces should be smaller where wages are higher, because Nike places smaller orders with factories that face higher wages or such factories use more automated methods of manufacturing. Accordingly, we control for wages.

Besides wages, the cost of labor also depends on the quality of the workforce. Areas with better infrastructure may attract more productive workers, whose superior productivity might not be fully absorbed by higher wages. Also, the quality of infrastructure affects the ability of workers to organize and seek better working conditions. Further, the cost of monitoring depends on the quality of infrastructure as well as distance. Accordingly, we control for infrastructure, as represented by the density of paved roads (area of paved roads divided by total prefecture area, in percentage). We lag both wages and road density by one year.

[2] http://info.worldbank.org/governance/wgi/pdf/rl.pdf

Figure 1 depicts the distribution of Nike contract factories by province, and Figure 2 depicts the distribution around the three regional hubs (Beijing, Shanghai, and Guangzhou) by prefecture. In the figures, the size of the circle represents the average factory workforce size.

Conventional manufacturing theory recommends that businesses leverage on economies of scale in production and economize on logistics (e.g., Pratten 1971; Cachon and Terwiesch 2013; Hausman et al. 2013). For Nike, this would imply concentrating production in a small number of factories close to major ports. By contrast, Figures 1 and 2 suggest that Nike spreads manufacturing over a wide geographical area, across and within provinces, including inland sites far from ports.

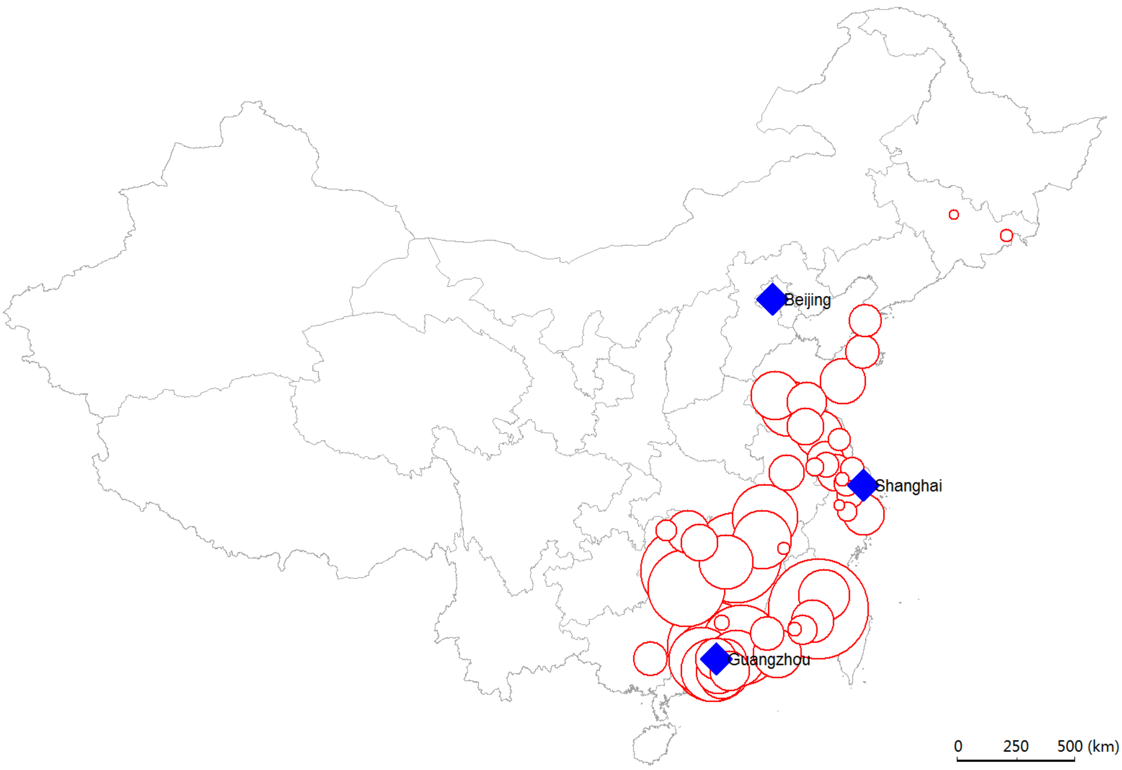
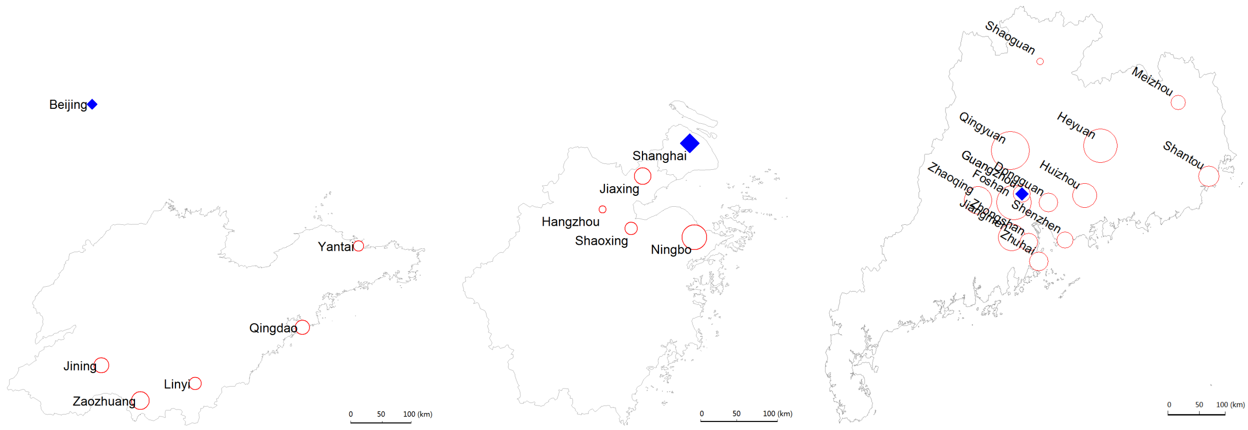


Figure 1 Nike's factory distribution in China

Table 2 reports summary statistics. We use the size of the workforce to represent the scale of production. The average factory employed 1,240 workers, of which 1,041 were line workers. The average wage is 53,588 Yuan per year (or US$ 8,506 at the average exchange rate of Yuan per



(a) (b) (c)

Figure 2 Nike's factory distribution in (a) Shandong, (b) Zhejiang, (c) Guangdong

US dollar in the period 2013 to 2016). The monitoring cost—distance of the factory from the closest regional hub divided by the number of factories in the prefecture—ranged between 0 and 948 kilometers per trip, with an average of 97 kilometers. The Wang et al. (2017) index of legal environment of business varied from 1.73 to 11.21, with an average of 7.37, and the index of intellectual property rights varied from 0.9 to 35.91, with an average of 18.66. Our construct for the rule of law is the average of the two indexes, which varies from 1.59 to 21.71, with an average of 13.01.

4.1. Estimates

Table 3 presents regressions of the scale of production on the cost of monitoring and rule of law. These are estimated by ordinary least squares with control for prefectural cost of labor (average wage) and infrastructure (road density), product category (footwear, apparel, and equipment) and brand (Nike, Hurley, and Converse), and fixed effects for provinces and years.[3] The province fixed effects control for systematic non-time-varying differences between the provinces that affect the scale of production across provinces, such as proximity to seaports. The year fixed effects control

[3] Equipment is omitted when we control for product category dummies; similarly, converse is omitted for brand dummies.

for systematic differences by year that affect the scale of production across all factories, such as the global macro-economy.

By way of background, Table 3, column (a), reports a regression on manufacturing wages, and controls for brands and product category, and fixed effects for provinces and years. The coefficient of wages, -14.53 (s.e. 7.55, $p < 0.1$), is negative and statistically significant. Consistent with intuition, Nike contract factories produce at smaller scale where wages are higher.

Table 3, column (b), reports an estimate including the cost of monitoring. The coefficient of the cost of monitoring, -2.17 (s.e. 0.75, $p < 0.01$), is negative and significant. Apparently, factories located further from regional hubs produced at smaller scale. The estimate implies that an increase in monitoring cost by one standard deviation is associated with the workforce being smaller by 343 workers (about 28 percent of the sample average). This result is consistent with our theory (Proposition 3) that the scale of production decreases in the cost of monitoring.

Next, we consider how the scale of production varies with the rule of law. Referring to Table 3, column (c), the coefficient of the rule of law is negative but not statistically significant. This insignificant result is consistent with our theoretical analysis which suggests that the rule of law has conflicting effects on the scale of production. (By increasing the effectiveness of monitoring, stronger rule of law leads the brand to increase production. On the other hand, by raising the supplier's cost, it induces the brand to reduce production.)

Table 3, column (d), report an estimate including the monitoring cost, rule of law, and their interaction. The coefficient of monitoring cost is negative and significant. Importantly, consistent with our theory (Proposition 4), the coefficient of the interaction between monitoring cost and the rule of law is positive and significant. For a factory located in a province with the average rule of law, an increase in the monitoring cost by one standard deviation is associated with 211 fewer workers (about 16 percent of the average workforce size), whereas for a factory located in a province with the mean plus one standard deviation rule of law, an increase in the monitoring cost by one standard deviation is associated with only 31 fewer workers.

These estimates are statistically significant and economically meaningful. They suggest that the rule of law positively moderates the negative relation between the scale of production and the cost of monitoring. One way to interpret this result is that Nike's compliance system combines in-person monitoring with application of the legal system. To manage compliance in factories that are more distant, Nike relies relatively more on the local legal system.

Overall, we prefer the estimate including the monitoring cost, rule of law, and their interaction. The negative and significant coefficient of the monitoring cost is consistent with our Proposition 3. The positive and significant coefficient of the interaction between monitoring cost and the rule of law is consistent with our Proposition 4. It implies that the rule of law has an economically meaningful effect on the scale of production and the cost of monitoring.

4.2. Robustness

Table 4, columns (a)-(e), report checks of robustness of our finding of a negative relation between the scale of production and cost of monitoring, positively moderated by the rule of law. In column (a), we exclude factories that produce for either the second or third largest manufacturers of athletic footwear, Adidas and Puma. Nike, Adidas, and Puma collectively accounted for over a quarter of world production of athletic footwear, increasing from 25.6 percent in 2013 to 32.3 percent in 2016.[4] We collected historical data on the Adidas and Puma contract factories from the Internet Archive Wayback Machine. Referring to Table 2, an average of 1 percent of Nike factories also produce for Adidas or Puma. (Among other major manufacturers, ASICS, New Balance, and Skechers do not publish the names of their contract factories.)

This robustness check is especially important to address the concern that some factories may not only produce for Nike, and so, their number of employees does not accurately represent production scale. However, operations data including order quantities is confidential corporate information and difficult to obtain. (For instance, we approached Adidas and Puma for data on workforce size at contract factories but received no response.) Although we cannot definitely rule out that some

[4] https://www.statista.com/statistics/278834/revenue-nike-adidas-puma-footwear-segment/

workers produce for manufacturers besides the top three, it is reasonable to assume that if a factory in our sample does not produce for Adidas and Puma, then a major part of its production can be attributed to Nike, and so, workforce size is a rough proxy for scale of production.

In columns (b) and (c), we check whether the results are sensitive to our measure of the rule of law. In column (d), we measure the scale of production by the number of line workers, as the total number of employees may include workers who are not directly engaged in manufacturing. Finally, in column (e), we exclude factories that are outliers in size to avoid the results being driven by the top and bottom 1% suppliers. Our finding is robust to all of these differences in measures and specification.

4.3. Alternative Explanations

One possible concern with our finding of a negative relation between factory size and monitoring cost is reverse causality. For various reasons, Nike might have chosen to spread its contract factories over a large geographical area. The costs of production and logistics might be higher in more remote locations, and so, Nike places smaller orders with factories further from regional hubs. This would yield a negative relation between factory size and distance.

This alternative hypothesis conflicts with conventional manufacturing strategy which would recommend that Nike concentrate production in a few factories close to major ports. By contrast, Figures 1 and 2 suggests that Nike disperses production among small factories over a large geographical area. Moreover, our estimates control for labor costs and infrastructure, and so, account for differences in the costs of production and logistics.

Nevertheless, to further check the alternative hypothesis, we estimate a specification controlling for distance to the nearest major port (Tianjin, Shanghai, and Shenzhen in the north, center, and south respectively). As Table 5, column (a), reports, the coefficient of distance to port is positive, suggesting that factories that are more distant from ports produce at larger scale, which conflicts with the alternative hypothesis. The coefficient of monitoring cost remains negative and significant, and the magnitude is comparable to the preferred estimate in Table 3, column (d). The coefficient of the interaction between the monitoring cost and rule of law is smaller than the preferred estimate, possibly due to the close correlation between distance to regional hub and distance to major port. (Beijing is close to Tianjin, Shanghai is both a regional hub and port, and Guangzhou is close to Shenzhen.)

Another possible interpretation of the negative relation between factory size and monitoring cost is the progressive expansion of manufacturing. As Nike expands procurement, it engages contract factories further away from the regional hubs. To limit risk, it awards smaller production contracts to new factories. Such an expansion strategy would yield a negative relation between factory size and distance.

However, while plausible, this explanation does not apply to Nike outsourcing strategy in China. Nike has actually reduced the number of contract factories in China, while expanding production in Vietnam and other countries in which wages are lower.

Nevertheless, to check the alternative hypothesis, we used the Internet Archive Wayback Machine to compile a list of Nike's contract factories in 2006. Ideally, we would like to use the contractual history of each factory to control for the relation between scale and Nike's progressive expansion. Absent such data, the 2006 data still helps to distinguish relatively older from new factories in our sample. Table 5, column (b), reports an estimate that controls for whether a factory produced for Nike before 2006. The coefficients of monitoring cost and its interaction with rule of law are robust and comparable to the preferred estimates. The coefficient of "Pre-2006 factories" is positive and significant, suggesting that older factories indeed are awarded larger production contracts.

An alternative explanation of why Nike spreads production geographically across multiple factories is to mitigate the risk of interruption of supply due to random shocks such as severe weather or labor strikes. To the extent that such shocks are independently distributed, Nike can reduce its overall risk by spreading orders. Rule of law might be correlated with better governance and resilience to natural shocks and better labor relations.

To check this alternative hypothesis, we perform estimates controlling for severe weather and unionization. For severe weather, we collect data at the province level on flood damage from the

China Yearbook of Meteorological Disasters and daily temperatures from the National Oceanic and Atmospheric Administration. Heavy rains causing floods could disrupt manufacturing and logistics. Extreme temperatures could affect worker productivity, and, if high enough, under Chinese law, require suspension of work.

Table 5, column (c), reports an estimate that controls for the number of buildings that collapsed due to floods and the number of days with average temperature exceeding 35° Celsius. The coefficient of floods is positive, suggesting that the scale of production is larger in provinces when floods were more severe, which is inconsistent with the alternative hypothesis. The coefficients of monitoring cost and its interaction with rule of law are almost the same as the preferred estimates.

Finally, we use unionization to proxy for the risk of labor strikes. We collect province-level data on employment and union membership from the China Labour Statistical Yearbook and China Trade Union Statistics Yearbook. Table 5, column (d), reports an estimate that controls for the ratio of unionized labor to employed workers. The coefficient of unionization is positive, suggesting that the scale of production is larger where more workers are unionized, which is inconsistent with the alternative hypothesis. The coefficients of monitoring cost and its interaction with law remain robust. We conclude that the empirical evidence weighs against the alternative hypothesis.

5. Discussion and Conclusion

Our work contributes to the operations management literature and managerial strategy in several ways. We show theoretically and confirm empirically that brands can use the scale reduction and monitoring as substitute ways to encourage responsible sourcing. When the cost of monitoring is higher, brands should temper production at each contract supplier so as to mitigate the contractor's incentive to evade responsible sourcing. This implies spreading production over a larger number of suppliers.

Stronger rule of law enhances the effectiveness of monitoring, but affects the production scale in conflicting ways. In theory, the more effective monitoring should reduce evasion and lead brands to increase scale. However, the more effective monitoring raises the supplier's cost of remediation, which inflates the wholesale price and cuts the product margin, and so, leads brand to reduce scale. Empirically, we find that stronger rule of law has no direct effect on production scale. However, stronger rule of law positively moderates the negative relation between production scale and monitoring cost.

Our findings also provide useful guidance to local governments in emerging economies such as China, Vietnam, and Bangladesh which seek investment in labor-intensive businesses to manufacture for international brands. It is well known that investment and exports depend on the costs of transportation and communication (Hausman et al. 2013). Here, we derive a more nuanced implication. The higher is the cost of monitoring, the smaller will be orders from international brands. The brands would spread orders over more suppliers, and possibly to other cities and regions. To attract larger export orders, local governments should improve transportation and communication. Another way is to establish an independent judiciary, develop lawyers, ensure fair police administration, and prosecute corruption. Stronger rule of law moderates the negative impact of high monitoring costs.

Our results highlight the importance of the rule of law in responsible outsourcing, and supply chain management more generally. So far as we are aware, the only previous OM research that considers the rule of law is by Hausman et al. (2013). They investigate the effect of logistics costs on international trade. Although their regression estimates show that corruption in importing and exporting countries has significant effects, the authors do not interpret the results.

We caution that our empirical analysis of Nike contract manufacturing is based on observational data. In particular, Nike contract factories are not randomly assigned across Chinese cities. Rather, they are concentrated in the coastal provinces, with Guangdong, Jiangsu, Zhejiang, and Shandong accounting for three-quarters of the factories. Yet, the wide dispersion within provinces suggests that Nike does distribute its manufacturing. Accordingly, our analysis which is based on within-province variation, may be fairly robust to endogenous choice of location.

Another limitation of our empirical analysis is that the dataset is limited to publicly-available information on Nike contract factories and does not include proprietary information such as order quantities or audit scores. Ideally, with data on order quantities and audit scores, we could more precisely test our theoretical propositions regarding how brands combine production scale and monitoring as mechanisms to induce suppliers to behave responsibly.

Another important direction for further research is the effect of supplier ownership. Locke et al. (2007) found that, in the Nike supply chain, foreign-owned factories received better audit scores. Apparently, foreign owners suffered relatively more from evasion than local owners. In earlier years, Nike outsourced manufacturing to Korea and Taiwan. As wages in those countries rose, Nike shifted production to China, Indonesia, and Vietnam, in part, using Korean and Taiwanese contractors (Nisen 2013). It would be interesting to investigate the role of Korean and Taiwanese intermediaries on responsible sourcing.

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Table 1 (Locke et al. (2007: Table 4)). Audit score

	(a)	(b)	(c)	(d)	(e)
Rule of Law	0.074***	0.04***	0.045***	0.047***	0.027**
	(0.0086)	(0.008)	(0.013)	(0.013)	(0.011)
No. of employees			-0.025***	-0.022***	-0.013**
(ln)			(0.007)	(0.007)	(0.007)
No. of SHAPE			0.002	0.002	0.0038*
inspections			(0.002)	(0.002)	(0.002)
Other factory characteristics	Yes	Yes	Yes	Yes	Yes
Region f.e.		Yes			Yes
Year f.e.				Yes	
R-squared	0.11	0.27	0.21	0.23	0.36
Observations	568	568	355	355	355

Notes: Dependent variable is score on first audit of management and working conditions (M-Audit); SHAPE refers to environmental, safety and health; All estimates include other factory characteristics (foreign/local ownership, whether the factory is a Nike strategic partner, months as Nike contractor, percentage of work for Nike, number of Nike inspections, product category (apparel, footwear, or equipment)) as controls, and constant.

Table 2. Summary statistics

	Unit	Mean	Standard deviation	Minimum	Maximum
Total workers	Persons	1,239.97	2,014.39	14.00	15,170
Line workers	Persons	1,040.87	1,685.74	6.00	11465
Average wages	Yuan per year	53,587.51	11,757.2	29,998.46	92,189.76
Road density	Percentage (%)	1.07	1.53	0.02	5.83
Monitoring cost	Index	96.52	158.23	0	947.69
Legal environment of business	Index	7.37	1.86	1.73	11.21
Intellectual property rights	Index	18.66	10.33	0.90	35.91
Rule of law	Index	13.01	5.67	1.59	21.71
Multi manufacturer	Indicator	0.01	0.12	0	1

Notes: Unit of analysis: factory-year; 667 observations of 246 factories in 12 provinces

Table 3. Nike: Production scale and monitoring costs

Variables	(a) Baseline	(b) Monitoring costs	(c) Rule of law	(d) Monitoring cost x Rule of law (Preferred estimate)
Footwear	2,291.28‡	2,275.19‡	2,274.67‡	2,247.57‡
	(277.13)	(274.18)	(274.24)	(274.57)
Apparel	272.75†	243.58†	241.94†	203.62*
	(112.86)	(114.16)	(114.02)	(117.63)
Nike brand	919.16‡	925.95‡	913.65‡	882.97‡
	(139.97)	(140.28)	(138.77)	(139.56)
Converse brand	-233.05*	-249.43*	-262.42*	-299.47†
	(134.14)	(135.10)	(133.74)	(136.19)
Road density	-24.03	-39.77	-31.21	-26.50
	(67.21)	(67.73)	(69.02)	(68.63)
Average wages	-14.53*	-22.12‡	-23.06‡	-21.36‡
	(7.55)	(8.26)	(8.30)	(8.23)
Monitoring cost		-2.17‡	-2.16‡	-3.93‡
		(0.75)	(0.75)	(1.42)
Rule of law			-30.83	-46.20
			(34.72)	(35.29)
Monitoring cost x Rule of law				0.20†
				(0.10)
Province f.e.	Yes	Yes	Yes	Yes
Year f.e.	Yes	Yes	Yes	Yes
R-squared	0.32	0.33	0.33	0.34
Observations	667	667	667	667
Factories	246	246	246	246
Provinces	12	12	12	12

Notes: Estimated by ordinary least squares; Omitted product category is equipment and omitted brand is Hurley; Robust standard errors clustered in parentheses (‡$p<0.01$, † $p<0.05$, * $p<0.1$).

Table 4. Nike: Production scale and monitoring costs: Robustness

Variables	(a) Produce for Nike only	(b) Legal environment	(c) Intellectual property rights	(d) Scale: Line workers	(e) Exclude outliers in size
Footwear	2,443.82‡	2,260.68‡	2,252.18‡	1,921.41‡	1,919.46‡
	(254.09)	(274.19)	(274.72)	(224.68)	(232.06)
Apparel	319.02‡	236.49†	206.78*	182.39*	212.37*
	(101.24)	(113.71)	(118.58)	(102.44)	(117.03)
Nike brand	864.54‡	905.85‡	886.05‡	765.63‡	743.71‡
	(139.24)	(136.88)	(140.79)	(115.60)	(108.99)
Converse brand	-229.36*	-270.57†	-295.84†	-267.07†	-354.15‡
	(132.20)	(131.10)	(138.03)	(114.61)	(109.91)
Road density	41.00	-12.70	-31.24	-24.36	-19.13
	(62.38)	(71.25)	(68.37)	(55.52)	(59.44)
Average wages	-24.02‡	-24.13‡	-21.17†	-18.23‡	-14.74†
	(7.82)	(8.49)	(8.21)	(6.71)	(7.15)
Monitoring cost	-3.73‡	-4.72‡	-3.23‡	-3.10‡	-3.30†
	(1.42)	(1.71)	(1.18)	(1.16)	(1.34)
Rule of law	-47.66			-38.89	-31.22
	(34.19)			(29.15)	(33.38)
Monitoring cost x Rule of law	0.20*			0.16*	0.19†
	(0.10)			(0.08)	(0.09)
Legal environment		-133.56			
		(112.81)			
Monitoring cost x legal environment		0.39*			
		(0.21)			
Intellectual property rights			-24.62		
			(19.53)		
Monitoring cost x intell prop rights			0.10*		
			(0.05)		
Province f.e.	Yes	Yes	Yes	Yes	Yes
Year f.e.	Yes	Yes	Yes	Yes	Yes
R-squared	0.36	0.34	0.34	0.35	0.33
Observations	657	667	667	667	653
Factories	245	246	246	246	246
Provinces	12	12	12	12	12

Notes: Estimated by ordinary least squares; Omitted product category is equipment and omitted brand is Hurley; Robust standard errors clustered in parentheses (‡ p<0.01, † p<0.05, * p<0.1)

Table 5. Nike: Production scale and monitoring costs: Alternative explanations

Variables	(a) Control for distance to port	(b) Control for pre-2006 factories	(c) Control for natural shocks	(d) Control for unionized labor
Footwear	2,232.75‡	2,116.07‡	2,247.04‡	2,251.66‡
	(273.51)	(249.21)	(275.50)	(274.54)
Apparel	168.42	109.77	199.66*	208.22*
	(118.58)	(121.76)	(118.72)	(118.24)
Nike brand	884.18‡	572.80‡	895.06‡	877.63‡
	(138.92)	(127.98)	(141.54)	(138.79)
Converse brand	-308.41†	-326.90†	-297.31†	-302.97†
	(136.18)	(129.72)	(137.79)	(135.12)
Road density	-3.55	-29.82	-26.85	-20.38
	(70.73)	(63.08)	(68.72)	(69.62)
Average wages	-17.87†	-23.26‡	-21.33‡	-22.26‡
	(8.44)	(8.03)	(8.22)	(8.27)
Monitoring cost	-3.77‡	-3.65‡	-3.78‡	-3.93‡
	(1.42)	(1.41)	(1.43)	(1.42)
Rule of law	-38.79	-50.61	-35.69	-57.36
	(34.99)	(35.46)	(37.04)	(40.84)
Monitoring cost x Rule of law	0.13	0.26‡	0.18*	0.20†
	(0.11)	(0.10)	(0.10)	(0.10)
Distance to the nearest port	1.90*			
	(1.10)			
Pre-2006 factory		1,334.01‡		
		(251.05)		
Flood damage			36.81	
			(101.19)	
Extreme temperature			-27.95	
			(25.75)	
Share of unionized workers				353.19
				(360.49)
Province f.e.	Yes	Yes	Yes	Yes
Year f.e.	Yes	Yes	Yes	Yes
R-squared	0.34	0.39	0.34	0.34
Observations	667	667	667	667
Factories	246	246	246	246
Provinces	12	12	12	12

Notes: Estimated by ordinary least squares; Omitted product category is equipment and omitted brand is Hurley; Robust standard errors clustered in parentheses (‡ p<0.01, † p<0.05, * p<0.1)

Appendix A1

Proof of Proposition 1.

$C(Q)$ is increasing, and $r''(x) > 0$, and so, $v' = 1/(r''v) > 0$. Moreover, similar to Equation (5), we can derive that

$$\frac{dx}{d\lambda} = -\frac{1}{\lambda^2 \mu}\ v' C(Q). \tag{A1}$$

Then, then proof is straightforward from Equations (4), (5), and (A1). When x takes on boundary values, increasing Q will no longer raise x, thus implying the weakly increasing property. Note that, if μ is sufficiently small, x converges to 1, thus implying the weakly decreasing property.

Proof of Proposition 2.

Suppose that the equilibrium is interior with $x^* < 1$ and $\mu^* > 0$. From (10), recall the first-order condition,

$$\frac{\partial \Pi}{\partial \mu} = [C(Q) - \lambda\mu r'(x) - \phi'(x)]\frac{dx}{d\mu} - \lambda r(x) - k. \tag{10}$$

Partially differentiating (10),

$$\frac{\partial^2 \Pi}{\partial Q \partial \mu} = \frac{d}{dQ}[C(Q) - \lambda\mu r'(x) - \phi'(x)]\frac{dx}{d\mu} + [C(Q) - \lambda\mu r'(x) - \phi'(x)]\frac{d^2 x}{dQ d\mu} - \lambda r'(x)\frac{dx}{dQ}. \tag{A2}$$

By the supplier's maximization, (2), we have

$$\frac{dx}{d\mu} = -\frac{r'(x)}{r''(x)\mu}, \tag{A3}$$

$$\frac{dx}{dQ} = \frac{C'(Q)}{r''(x)\lambda\mu}. \tag{A4}$$

On the right-hand side of (A2), the first term

$$\begin{aligned} \frac{d}{dQ}[C(Q) - \lambda\mu r'(x) - \phi'(x)]\frac{dx}{d\mu} &= \left[C'(Q) - \lambda\mu r''(x)\frac{dx}{dQ} - \phi''(x)\frac{dx}{dQ}\right]\frac{dx}{d\mu} \\ &= -\left[\frac{\phi''(x)}{r''(x)\lambda\mu}C'(Q)\right]\frac{dx}{d\mu} = \frac{\phi''(x) r'(x)}{[r''(x)]^2\mu^2\lambda}C'(Q), \end{aligned} \tag{A5}$$

after first substituting from (A4) and then (A3).

The second term on the right-hand side of (A2),

$$[C(Q) - \lambda\mu r'(x) - \phi'(x)]\frac{d^2x}{dQd\mu} = -\phi'(x)\frac{d^2x}{dQd\mu}, \tag{A6}$$

since, by (2), $C(Q) = \lambda\mu r'(x)$. Now, differentiating $dx/d\mu$ with respect to Q and substituting from (A4),

$$\frac{d^2x}{dQd\mu} = -\frac{[r''(x)]^2 - r'(x)r'''(x)}{[r''(x)]^2\mu}\frac{dx}{dQ} = -\frac{[r''(x)]^2 - r'(x)r'''(x)}{[r''(x)]^3\mu^2\lambda}C'(Q).$$

Substituting in (A6), the second right-hand side term of (A2) simplifies to

$$\phi'(x)\frac{[r''(x)]^2 - r'(x)r'''(x)}{[r''(x)]^3\mu^2\lambda}C'(Q). \tag{A7}$$

Lastly, the third term on the right-hand side of (A2) is

$$-\lambda r'(x)\frac{dx}{dQ} = -r'(x)\frac{C'(Q)}{r''(x)\mu}, \tag{A8}$$

after substituting from (A4).

Combining the three terms, (A2) simplifies to

$$\begin{aligned}\frac{\partial^2\Pi}{\partial Q\partial\mu} &= \frac{\phi''(x)r'(x)}{[r''(x)]^2\mu^2\lambda}C'(Q) + \phi'(x)\frac{[r''(x)]^2 - r'(x)r'''(x)}{[r''(x)]^3\mu^2\lambda}C'(Q) - r'(x)\frac{C'(Q)}{r''(x)\mu} \\ &= \frac{C'(Q)}{[r''(x)]^3\mu^2\lambda}\left\{r'(x)r''(x)[\phi''(x) - \lambda\mu r''(x)] + \phi'(x)[(r''(x))^2 - r'(x)r'''(x)]\right\}. \end{aligned} \tag{A9}$$

As $C'(Q) > 0$ and $r''(x) > 0$, $C'(Q)/[(r''(x))^3\mu^2\lambda] > 0$. Since $r'(x)$ is weakly concave, then $[r''(x)]^2 - r'(x)r'''(x) > 0$. Since $\phi''(x) > \lambda r''(x)$ and $\mu \in [0,1]$, $r'(x)r''(x)[\phi''(x) - \lambda\mu r''(x)] > 0$. Thus, $\partial^2\Pi/\partial Q\partial\mu > 0$.

Proof of Proposition 3.

There are two possible classes of equilibrium. One is interior with $x^* < 1$ and $\mu^* > 0$. The other is a boundary case with $\mu^* = 0$ and $x^* = 1$. Note that, in any equilibrium, if $\mu^* = 0$, then the supplier is entirely undisciplined, and so, $x^* = 1$. If $x^* = 1$, then monitoring yields no benefit, and so, $\mu^* = 0$.

Consider the interior equilibrium with $x^* < 1$ and $\mu^* > 0$. To characterize the effect of the cost of monitoring on the scale of production, evaluate

$$\frac{d^2\Pi}{dkdQ} = \frac{\partial^2\Pi}{\partial k\partial Q} + \frac{\partial^2\Pi}{\partial\mu\partial Q}\cdot\frac{\partial\mu}{\partial k} < 0, \tag{A10}$$

since, by (8), $\partial^2\Pi/\partial k\partial Q = 0$, and by (10), $\partial\mu/\partial k < 0$, and using Proposition 2. To characterize the effect of the cost of monitoring on the monitoring rate, evaluate

$$\frac{d^2\Pi}{dkd\mu} = \frac{\partial^2\Pi}{\partial k\partial\mu} + \frac{\partial^2\Pi}{\partial Q\partial k} \cdot \frac{\partial Q}{\partial k} < 0, \tag{A11}$$

since, by (10), $\partial^2\Pi/\partial k\partial\mu < 0$, and by (8), $\partial Q/\partial k = 0$. Accordingly, we conclude that Q and μ both decrease with k.

Now consider the boundary case of $\mu^* = 0$ and $x^* = 1$. Then, the brand's maximization problem effectively reduces to choosing Q to maximize $\Pi = p(Q)Q - \lambda\mu r(1) - \phi(1)$, which is independent of the cost of monitoring, k.

Proof of Proposition 4.

Given the assumptions on $\phi(\cdot)$ and $r(\cdot)$, we first establish a few derivatives before discussing the effect of λ. First, rewrite (8) as

$$\frac{\partial\Pi}{\partial Q} = p'(Q)Q + p(Q) + \left[-1 + \frac{C(Q) - 2\phi x}{2r\lambda\mu}\right] C'(Q).$$

Partially differentiating with respect to λ,

$$\frac{\partial^2\Pi}{\partial\lambda\partial Q} = -\frac{C(Q) - 2\phi x}{2r\lambda^2\mu}C'(Q) + \frac{2\phi x}{2r\lambda^2\mu}C'(Q) = [4\phi x - C(Q)]\,\frac{C'(Q)}{2r\lambda^2\mu} > 0, \tag{A12}$$

since, by (12), we have $C(Q) < 2\lambda\mu rx + 2\phi x$, and, by assumption, $\phi > \lambda r$, and so,

$$4\phi x > C(Q). \tag{A13}$$

Second, we can also rewrite (10) as

$$\frac{\partial\Pi}{\partial\mu} = -[C(Q) - 2\lambda\mu rx - 2\phi x]\frac{x}{\mu} - k - \lambda rx^2. \tag{A14}$$

Partially differentiating with respect to Q, substituting from (A4), and simplifying yields

$$\frac{\partial^2\Pi}{\partial Q\partial\mu} = [4\phi x - C(Q)]\frac{C'(Q)}{2r\lambda\mu^2} > 0. \tag{A15}$$

For the effect of k on $d^2\Pi/d\lambda dQ$, evaluate

$$\frac{d^3\Pi}{dkd\lambda dQ} = \frac{\partial^3\Pi}{\partial k\partial\lambda\partial Q} + \frac{\partial^3\Pi}{\partial\mu\partial\lambda\partial Q}\frac{\partial\mu}{\partial k} = \frac{\partial^3\Pi}{\partial\mu\partial\lambda\partial Q}\frac{\partial\mu}{\partial k}, \tag{A16}$$

since, by partially differentiating (A12) with respect to k, we have $\partial^3\Pi/\partial k\partial\lambda\partial Q = 0$. By Proposition 3, we know that $\partial\mu/\partial k < 0$, and hence the sign of $d^3\Pi/dkd\lambda dQ$ depends on

$$\frac{\partial^3\Pi}{\partial\lambda\partial Q\partial\mu} = -4\phi x\frac{C'(Q)}{2r\lambda^2\mu^2} - [4\phi x - C(Q)]\frac{C'(Q)}{2r\lambda^2\mu^2} < 0.$$

Thus, $d^3\Pi/dkd\lambda dQ > 0$, which implies that, in equilibrium, if k and λ simultaneously increase, it is profit-maximizing to increase Q as well.

Remark. *The sign of* $d^2\Pi/d\lambda dQ$ *is ambiguous, i.e., the sign of the main effect of the rule of law on production scale is ambiguous.*

Proof of Remark.

Evaluate

$$\frac{d^2\Pi}{d\lambda dQ} = \frac{\partial^2\Pi}{\partial\lambda\partial Q} + \frac{\partial^2\Pi}{\partial\mu\partial Q}\frac{d\mu}{d\lambda}. \tag{A17}$$

By (A12), the first right-hand side term is positive. By (A15), $\partial^2\Pi/\partial\mu\partial Q > 0$, and, so if $d\mu/d\lambda < 0$, and then the second right-hand side term is negative, and, accordingly, the sign of $d^2\Pi/d\lambda dQ$ is ambiguous.

To show that $d\mu/d\lambda < 0$, recall from (A14) that μ satisfies

$$-[C(Q) - 2\lambda\mu rx - 2\phi x]\frac{x}{\mu} = k + \lambda rx^2.$$

Differentiating with respect to λ on both sides,

$$[C(Q) - 2\phi x]\frac{x}{\mu^2}\frac{d\mu}{d\lambda} = -[C(Q) - \lambda\mu rx - 4\phi x]\frac{x}{\lambda\mu}.$$

By (A13), $C(Q) < 4\phi x$, and so, the right-hand side above is negative, and the sign of $d\mu/d\lambda$ depends on the sign of $C(Q) - 2\phi x$.

By assumption, $r(x) = rx^2$, and so, (2) simplifies to

$$x = \frac{C(Q)}{2r\lambda\mu}.$$

Further, by assumption, $\phi > \lambda r$, and so,

$$x = \frac{C(Q)}{2r\lambda\mu} > \frac{C(Q)}{2r\lambda} > \frac{C(Q)}{2\phi}.$$

Hence, $C(Q) - 2\phi x < 0$, and so, $d\mu/d\lambda < 0$.

Appendix A2

Table A1. Variables

Variable	Detailed construction	Source
Nike Supplier Factories		
Total workers	Number of workers in each factory	Nike
Line workers	Number of assembly line workers in each factory	
Footwear	= 1 if the factory produces footwear; = 0 otherwise	
Apparel	= 1 if the factory produces apparel; = 0 otherwise	
Equipment	= 1 if the factory produces equipment; = 0 otherwise	
Nike brand	= 1 if the factory produces for Nike brand; = 0 otherwise	
Converse brand	= 1 if the factory produces for Converse brand; = 0 otherwise	
Hurley brand	= 1 if the factory produces for Hurley brand; = 0 otherwise	
Multi manufacturer	= 1 if the factory is also a supplier for Adidas or Puma; = 0 otherwise	Nike, Adidas, Puma
No. of SHAPE inspections	Number of environmental, safety and health audits of the factory conducted by Nike	Locke et al. (2007)
Covariates		
Road density	Area of paved roads (10,000 square meters) divided by land area of the prefecture (square kilometers)	China City Statistical Yearbook
Average wages	Average wage of employees (excluding private sector and self-employment)	
Monitoring cost	Geodesic from the prefecture in which the factory is located to the nearest regional hub (Beijing, Shanghai, or Guangzhou), divided by number of Nike contract factories in the prefecture	GPS coordinates from Google Map; geodesic computed by Stata routine, geodist
Distance to the nearest port	Geodesic from the prefecture in which the factory is located to the nearest major port (Tianjin, Shanghai, or Shenzhen)	
Flood damage	Number of buildings collapsed due to rainstorm-induced flood (including landside and mud-rock flow) by province	Yearbook of Meteorological Disasters in China
Extreme weather	Number of days with daily average temperature above 35 degrees Celsius, at the closest weather station	NOAA Climate.gov[1]
Unionization	The cumulative number of union members in each province divided by the total number of workers in the province	China Labour Statistical Yearbook and China Trade Union Statistics Yearbook
Rule of Law Indexes		
Legal environment	Business owners' assessment of justice and effectiveness of law enforcement, as reported by China Entrepreneur Survey System	Wang et al. (2017) [2]
Intellectual property rights	Number of patent applications per science and technology staff	
Rule of law index	Average of "legal environment" and "intellectual property rights"	Author's calculation

[1] URL: https://www.climate.gov/maps-data/dataset/daily-weather-statistics-graph-or-data-table.

[2] In Wang et al. (2017), the indexes are published every two years from 2008 and standardized using the formula $I_t = (I_{t0} - I_{min})/(I_{max} - I_{min})$x10, where I is the rescaled index in year t, I_0 is the raw index in year t, I_{min} and I_{max} are the minimum and maximum values of all provincial indexes in year 2008. We linearly interpolate for years 2013 and 2015 using the data for 2012, 2014 and 2016.