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Original Article

Does the maturity of company-specific production systems predict operational performance in multinational plants?

¿La madurez del sistema técnico XPS predice el desempeño operativo en plantas multinacionales?

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Abstract

Introduction: Company-specific production systems (XPS) are the corporate programmes through which multinational manufacturers deploy Toyota-inspired practices across their plant networks. Performance is held to depend on the maturity attained rather than on adoption itself, yet this has been tested almost only within single corporations.
Objective: To test whether technical-system maturity predicts high operational performance across firms and sectors, and whether the association is graded or threshold-like.
Methodology: Cross-sectional survey of 316 plants of multinational manufacturers in four sectors in Mexico. Maturity was operationalised as a four-level nested hierarchy requiring simultaneous deployment of the twelve technical-system practices of the House of the Toyota Production System. High performance was derived by two-cluster k-means on seven indicators, and associations by Firth penalised logistic regression adjusted for programme age, plant size and sector.
Results: The proportion of plants attaining high operational performance rises monotonically across maturity levels, from 21.7 to 46.5, 71.9 and 88.2 per cent, with an odds ratio of 3.00 per step ($p < 0.001$) that survives full adjustment. Neither plant size nor sector discriminates, and programme age loses its independent effect once maturity is controlled.
Conclusions: To the best of the author's knowledge, this is the first test of the proposition across firms and sectors in Mexico. What distinguishes plants is the completeness of deployment.

Keywords: company-specific production systems; implementation maturity; operational performance; multinational enterprises; lean manufacturing.

Resumen

Introducción: Los sistemas de producción específicos de la compañía (XPS) son los programas con los que las multinacionales despliegan prácticas inspiradas en Toyota en sus plantas. Se sostiene que el desempeño depende de la madurez alcanzada y no de la adopción, pero se ha contrastado casi solo dentro de una corporación.
Objetivo: Contrastar si la madurez del sistema técnico predice el alto desempeño operativo entre empresas y sectores, y si la asociación es gradual o de umbral.
Metodología: Encuesta transversal a 316 plantas de multinacionales manufactureras de cuatro sectores en México. La madurez se operacionalizó como jerarquía anidada de cuatro niveles que exige desplegar a la vez las doce prácticas del sistema técnico de la Casa del TPS. Las asociaciones se estimaron con regresión penalizada de Firth, ajustada por antigüedad, tamaño y sector.
Resultados: La proporción de plantas con alto desempeño asciende de forma monótona entre niveles de madurez: 21.7, 46.5, 71.9 y 88.2 por ciento, con una razón de momios de 3.00 por escalón ($p < 0.001$) que sobrevive al ajuste. Ni el tamaño ni el sector discriminan, y la antigüedad pierde su efecto al controlar por madurez.
Conclusiones: En el mejor conocimiento del autor, éste es el primer contraste de la proposición entre empresas y sectores en México. Lo distintivo es la completitud del despliegue.

Palabras clave: Palabras clave: sistemas de producción específicos; madurez de implementación; desempeño operativo; empresas multinacionales; manufactura esbelta.

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Why was the study conducted?
Many multinational plants in Mexico implement corporate lean production systems inspired by the Toyota Production System, yet results vary considerably among them. Previous studies measured the number of practices adopted by a plant or the duration of its program, but not the degree to which those practices were implemented throughout the entire plant. We sought to determine whether the maturity of such implementation predicts operational performance.

What were the key findings?
Across 316 plants, the proportion of high-performing plants increased progressively with maturity—from 21.7% in plants with incomplete implementation to 88.2% in plants where all twelve practices were fully implemented (an odds ratio of 3.00 per level). This relationship is gradual, with no single threshold. It holds true even after controlling for program duration, plant size, and industry sector. Program duration matters only insofar as it allows a plant to reach maturity, while neither industry sector nor plant size explains performance.

What do these findings contribute?
They demonstrate that performance depends on the extent of implementation across the entire technical system, rather than on the duration of the program or the industry sector to which the plant belongs. For managers, every level of implementation is beneficial; therefore, corporate programs should drive the full adoption of all practices, rather than simply waiting for the program to mature on its own.

Graphical Abstract

Does the maturity of company-specific production systems predict operational performance?

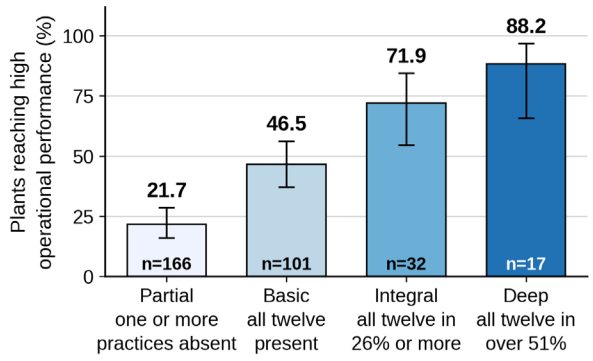
XPS technical-system maturity in 316 multinational manufacturing plants in Mexico

Population

Plants of multinational manufacturers running a company-specific production system (XPS) in Mexico: aerospace, automotive, electronics and medical devices.

Measure

Maturity of the XPS technical system is conjunctive: one threshold applied to all twelve practices at once, so an intensively deployed practice cannot make up for an absent one.



Result

OR = 3.00 per additional step of maturity (95% CI 2.20-4.22; $p < 0.001$; n = 316).

Estimation

Firth penalised logistic regression with profile-likelihood intervals, adjusted for programme age, plant size and sector. Replicated in R.

Performance responds to completeness, not to intensity: what distinguishes plants is the practice they have not started.

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Bars: 95% Wilson intervals

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Introduction

Multinational manufacturers rarely adopt lean production as a generic toolkit. They design their own company-specific production system, an XPS, in which the X stands for the corporate name, and deploy it as a strategic long-term programme across their plant network (1). The purpose is to have every plant operate under the same set of principles and improve according to the same system, so that operating practices proven in one location can be reused elsewhere (2). Volvo, Bosch and Mercedes all run such programmes, and their content is overwhelmingly drawn from the Toyota Production System (TPS) and lean production (1,3).

A programme, however, is not an outcome. The claim that has organised research on XPS for the past decade is that operational performance depends not on having adopted the programme but on how far its deployment has progressed. In the reference study on the Volvo Production System, the relationship between implementation maturity and operational performance was found to follow an S-shape, with each of the model's principles behaving alike (4,5). Because that study spanned plants in several countries and continents with different products and processes, it controlled for corporate culture, industry and technology, and its authors concluded that maturity may be the single most important factor explaining performance differences between plants, ahead of contextual attributes such as plant size (6), the development level of the host country (7) or organisational culture (8).

That conclusion carries an inferential cost that has gone largely unexamined. Controlling contingencies by staying inside one corporation is also what prevents the finding from travelling: in a single-firm design, corporate culture, programme content, measurement instruments and managerial attention are held constant by construction, and it is precisely those factors that vary when a plant belongs to a different multinational. Whether the maturity–performance association survives across firms, across corporate programmes with different content, and in an emerging-economy manufacturing base is therefore an open empirical question rather than an established result.

A second gap concerns the shape of the relationship. Maturity is routinely treated as a scalar quantity, and the empirical literature has tended to dichotomise it into high and low (9,10). Yet the managerial implication differs sharply depending on whether the association is graded or threshold-like. If graded, every increment of deployment buys performance and incremental investment is rational; if threshold-like, partial deployment buys nothing and the only rational strategy is to reach the threshold or not start. Distinguishing the two requires measuring maturity at more than two levels and reporting the full response profile, which is rarely done.

A third gap is measurement. Composite lean scores are typically built as averages across practices (6,11), an operation that allows an intensively deployed practice to compensate for an absent one. If, as the sociotechnical reading of lean holds, the technical system derives its effect from the interaction among its parts rather than from their sum (8,12,13,14), then an average is the wrong functional form: it will register as mature a plant that has saturated the cheap practices and never

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started the expensive ones. A measure requiring simultaneous presence is theoretically preferable, but its empirical superiority has not been demonstrated.

These three gaps meet in a practical observation: partial deployment is not a transient stage but a stable state. Recent evidence attributes the failure to sustain improvement programmes to organisational rather than technical causes, and finds the same causes recurring across countries and sectors (15,16); structured deployment models are proposed precisely because sustainment does not follow from adoption (17). Studies of implementation barriers converge on the same reading, identifying constraints that cut across the plant rather than residing in any single practice (18), and work on the critical success factors of lean strategy in manufacturing reaches it from the opposite direction (19,20). What none of this literature settles is how far deployment must progress before performance responds.

The question carries particular weight in emerging economies, where multinational plants operate under resource and capability constraints that the reference studies of the programmes did not face (7). Those constraints bear on each of the three gaps. The XPS is designed at corporate headquarters for the whole network (1,2), but each subsidiary deploys it with the engineering staff, training capacity and investment budget available locally, so the plant itself decides which practices to start first and how far to extend each one. Partial deployment in such a plant is therefore an allocation outcome as well as a stage of progress. The shape of the relationship then bears directly on that allocation: under a graded response every practice brought into operation yields a return the plant can demonstrate to its corporation, whereas under a threshold response resources spent short of the threshold yield nothing. The measurement problem is also sharper, because the practices deferred under resource constraints tend to be the costly ones that cross departmental boundaries, which is the pattern an average conceals. Roadmaps developed for these settings treat operational excellence as a staged progression rather than a binary state (21), and global comparisons of deployment across sectors report wide variation in how far organisations advance along it (22). Case evidence from Latin American plants shows the same pattern at the level of the individual site (23). Whether the returns to deployment under these constraints are graded or depend on a threshold has not been tested in a cross-firm population of plants.

This study addresses the three gaps together. Using a cross-sectional survey of 316 plants belonging to multinational manufacturers operating in Mexico across four sectors, it tests whether the maturity of the technical system predicts high operational performance across firms rather than within one, whether the association is graded, and whether a maturity measure built on simultaneous deployment discriminates. Mexico offers an informative setting: it is one of the largest manufacturing export platforms in the world, its plants belong overwhelmingly to foreign multinationals running their own XPS, and it therefore supplies precisely the cross-firm variation that single-corporation designs cannot. Prior Mexican evidence has documented the impact of individual lean tools on plant outcomes (24) and the predominance of partial rather than integral adoption in the maquiladora base (25). A previous study on an earlier portion of the same survey established which practices are adopted and showed that adoption does not differ significantly across industry sectors (26). What remains unexamined is whether the maturity of the technical system, taken as a system, predicts what plants actually achieve: that earlier work describes

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adoption but carries no performance outcome, and the question of consequence has therefore not been posed.

Theoretical background and hypotheses (The technical system of XPS models)

The two pillars of the TPS, just-in-time and jidoka, were identified in the first English-language account of the system (27) and have organised every subsequent representation of it. The House of the TPS arranges the technical practices accordingly: a base of process stability, two pillars, and a roof standing for the intended outcomes of quality, lead time and cost (28). Published versions of the house differ in what they place at the centre, which is the social component, but not in the technical practices that make up base and pillars. The diffusion of these practices beyond Toyota, and the consolidation of lean production as the dominant manufacturing paradigm, are documented in recent syntheses of the model's origins and of the way its concepts have been carried into other settings (28).

Analysis of thirty XPS models from recognised multinationals established that no two are identical, that all share the same principles with different emphases, and that their common content leans towards the technical side of the TPS rather than the human and cultural side (1). Notably, the two pillars themselves are not among the most frequent principles of the average XPS, whereas leadership, teamwork and employee involvement appear with intermediate frequency. For the purposes of measurement this is convenient: the technical system is the part of the XPS that is both consistently present across corporate programmes and consistently described in comparable terms, which makes it the tractable object for a cross-firm study.

Maturity and its two dimensions

Maturity in a multi-plant improvement programme has been decomposed into two dimensions (4,29). The first is the breadth of transfer, that is, the degree to which the company's model conforms to the reference model it draws on – for an XPS, to the TPS and lean production. Conformance is integral when the prescribed practices are adopted as a set, and partial when only some are implemented in isolation. The second is the depth of implementation, meaning how thoroughly and how widely each practice is actually deployed inside the plant. Elapsed time since programme launch has been used as a proxy for maturity but has been shown to be insufficient (4).

The distinction matters for the functional form of the measure. Breadth is a conjunctive property: a model conforms to the reference only if all of its constituent practices are present. Depth is a matter of degree. A measure that respects both must therefore be conjunctive in breadth and graded in depth – which is exactly what an average fails to be, and what a nested hierarchy of thresholds applied simultaneously to all practices achieves.

Hypotheses

Maturity models are the usual instrument for this purpose, and their construction is itself an active methodological problem. Self-assessment models make the stages explicit but leave the thresholds to the respondent (30); recent work on maturity models in manufacturing argues that their levels

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should be derived and validated rather than asserted (31), and scale-development studies show that the excellence construct is measured with markedly different item sets across studies (32). Applied to lean specifically, the assessment of development practices has been shown to depend heavily on where the levels are cut (9). The measure used here responds to that concern by fixing a single rule and moving one threshold.

The central proposition of the maturity literature, transposed from the single-corporation setting to a cross-firm one, yields the first hypothesis. If maturity rather than adoption drives performance, and if that mechanism is a property of production systems rather than of any one corporate programme, the association should be observable in a population of plants belonging to different multinationals.

H1. The maturity of the technical system is positively associated with the attainment of high operational performance.

The S-curve account implies more than a positive association: it implies that performance responds to deployment continuously over the middle of the range, with flat segments only at the extremes (4). Over the range observable in a general manufacturing population, where very few plants reach the highest levels, this predicts a graded rather than a threshold response.

H2. The association is graded: the probability of high operational performance increases monotonically across successive levels of maturity.

Finally, if maturity is the operative variable, the contextual attributes that a large literature has proposed as explanations of performance differences should not displace it, and elapsed programme time should not exert an effect of its own once maturity is held constant (4,6,8).

H3. The association between maturity and high operational performance persists after adjustment for programme age, plant size and industry sector.

Methodology (Research design)

The study is quantitative, non-experimental and cross-sectional, and its scope is explanatory-correlational: it tests hypotheses about the association between two constructs measured at a single point in time, without manipulating either. The unit of analysis is the plant, and each plant is represented by one qualified informant. Three features of the research problem determined this route.

First, the question concerns generality across firms, which requires plants that belong to different multinationals and run different corporate programmes. No public source records the deployment of XPS practices plant by plant, so the data had to come from informants inside the plants, and a structured survey administered under a common protocol is the instrument that reaches enough of them to estimate the association with adjustment for controls. Second, records of maturity that are comparable across corporations and repeated over time are not available, and a single-firm panel would reintroduce the restriction the study seeks to remove (4). A cross-sectional design

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is therefore the feasible first test: it can establish whether the association exists across firms and describe its shape, while its direction rests on the theoretical argument of Section 1.1 and remains to be confirmed longitudinally. Third, there is no sampling frame that lists multinational plants in Mexico together with the existence and age of their lean programmes, which rules out probabilistic sampling. Informants were therefore selected purposively by position and expertise, and inference refers to plants with an operating lean programme in the four sectors studied; the proportions reported are not extrapolated to Mexican manufacturing as a whole.

These choices also fixed the analytical strategy before the data were examined. Because the outcome is binary and the highest maturity level was expected to contain few plants, penalised logistic regression was specified a priori (Section 2.4). Because predictor and outcome come from the same informant, the instrument incorporated two procedural remedies, anonymity of the response (see Declarations) and a behavioural coverage scale for the practices (Section 2.3), and statistical diagnostics of common method variance were planned for the analysis stage (Section 2.4).

Sample and data collection

The population of interest was plants of multinational manufacturing firms operating in Mexico. The study was delimited to four sectors, automotive, electrical and electronics, aerospace and medical devices, for four reasons: they form the core of multinational export manufacturing in Mexico; they are industries in which company-specific production systems have been documented (1,3); their customers require certified quality management systems (IATF 16949 in automotive, AS9100 in aerospace, ISO 13485 in medical devices and, commonly, ISO 9001 in electronics), so continuous-improvement functions staffed by informants able to report deployment are formally established in their plants; and each sector supplies enough plants to estimate the sector contrasts that H3 requires. Qualified informants were identified through LinkedIn Recruiter, a professional profile-search platform, using two selection criteria: holding a managerial or engineering position, preferably in continuous-improvement functions, and having direct knowledge and experience of lean manufacturing and the TPS. A structured questionnaire was administered through a specialised online platform. Data collection concluded in July 2026. Invitations were sent individually through LinkedIn, so their exact number was not recorded; approximately 2,600 informants were contacted, which corresponds to a response rate of about 12 per cent. Complete responses were obtained for 316 plants, distributed across four sectors: automotive (157), electrical and electronics (67), aerospace (49) and medical devices (43). The 316 plants do not constitute a census of these sectors. They are the plants for which a qualified informant was reached and returned a complete questionnaire, drawn from a population of multinational plants in the four sectors that is considerably larger and for which no complete list exists. The sample is therefore non-probabilistic and purposive, as justified in Section 2.1. Two records with identical responses on every item were detected during screening; they were kept in the main analysis, and the effect of excluding them is reported in Section 3.4. Several multinationals are represented by more than one plant. Each plant has its own management, its own level of deployment and its own performance record, so the plant is the unit of analysis and plants belonging to the same firm enter the analysis as distinct observations. Plants of the same multinational need not share a common level of progress: in the

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reference study, plants running the same corporate programme differed widely in implementation maturity (4). Maturity is therefore treated as a property that each plant attains within its corporate programme, and the sample supplies the variation between firms that H1 requires.

Measures

Technical-system practices. Twelve practices prescribed in the House of the TPS were measured: lot-size reduction, value stream mapping, cellular layout, pull system, quick changeover (SMED), levelled and mixed production, total productive maintenance, quality at the source with error-proofing devices, automated defect detection (jidoka), standard work, visual management and controls, and 5S. Because the construct of interest is the extent of deployment rather than the informant's opinion of it, each practice was measured as the coverage attained within the plant on a five-level ordinal scale: (1) 0 per cent of the plant, (2) 1-25 per cent, (3) 26-50 per cent, (4) 51-75 per cent and (5) more than 75 per cent. Internal consistency was adequate (Cronbach's alpha = 0.906). The choice of a coverage rather than an agreement scale follows evidence that lean effects are tied to the extent of actual deployment across industries and plant sizes (33). The absence of consensus on which practices constitute the lean system (10,32) was handled by adopting the House of the TPS as the selection frame, since it is the model that XPS programmes declare as their source (1), thereby avoiding discretionary selection.

Maturity of the technical system. Following the two-dimensional definition (4), maturity was operationalised as a four-level nested hierarchy in which each level contains the next and the same threshold is applied simultaneously to all twelve practices: Partial, at least one practice entirely absent; Basic, all twelve present; Integral, all twelve deployed in at least 26 per cent of the plant; and Deep, all twelve deployed in more than 51 per cent of the plant. The conjunctive form prevents an intensively deployed practice from compensating for an absent one, which is the behaviour an average would permit.

High operational performance. Seven operational indicators were measured: customer satisfaction with product quality and with delivery times, and three-year change in rolled throughput yield, scrap and rework, cycle time, manufacturing cost and delivery lead time. The dependent variable was derived by two-cluster k-means on the standardised indicators, with 50 initialisations and a fixed seed; the cluster with the higher overall mean was labelled high operational performance. Internal consistency of the seven indicators was adequate (alpha = 0.864).

Control variables. Programme age was measured as years since the start of lean implementation on a five-level ordinal scale; plant size as number of employees on a four-level ordinal scale; and sector as a set of indicator variables with aerospace as the reference category.

Analysis

Associations were estimated with logistic regression using Firth's penalised-likelihood correction (34). The correction was chosen a priori because the highest maturity level contains few plants and the resulting sparse cells produce quasi-complete separation, under which maximum-likelihood estimates diverge or are severely biased away from the null (35). Confidence intervals were

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obtained by profile penalised likelihood rather than Wald approximation, and p-values by penalised likelihood-ratio tests. A trend test was performed by entering the maturity level as a single ordinal predictor. Robustness was assessed against alternative definitions of the dependent variable, alternative maturity thresholds, and exclusion of duplicated records. Common method variance was examined with Harman's single-factor test and with the marker-variable technique (36), taking years of experience in the current role as a marker theoretically unrelated to both constructs. Analyses were run in R 4.3.3 using the brglm2 package, which implements Firth's correction through mean-bias-reducing adjusted score equations, equivalent in logistic regression to penalisation by the Jeffreys prior (37). Figure 1 summarises the construction of both constructs and the model estimated.

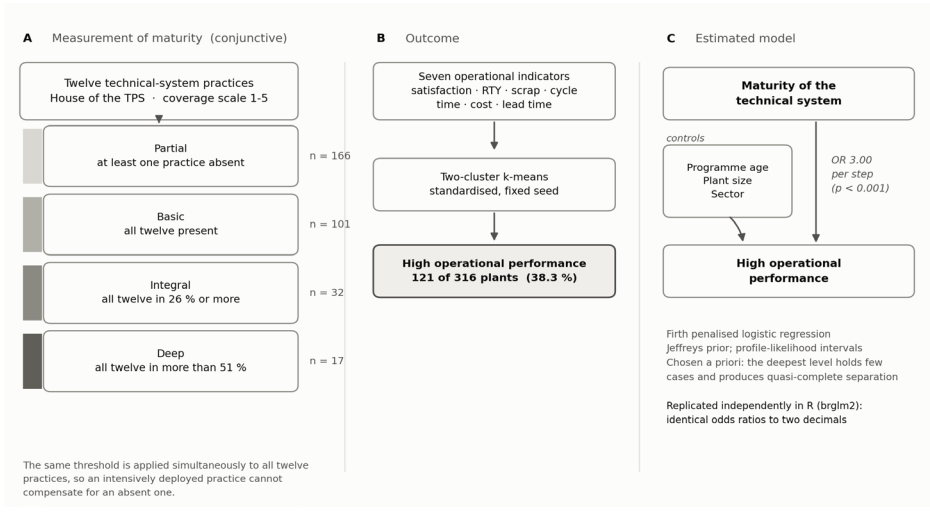

Figure 1. Construction of the two constructs and the estimated model. Panel A, the twelve technical-system practices and the four nested maturity levels; panel B, derivation of the outcome; panel C, the estimated association and its control variables.

Results

Distribution of maturity

Table 1 reports the distribution of maturity by sector, included here to characterise the sample rather than as a finding: the adoption profile of this population, and the absence of significant sectoral differences in it, are established in the previous study (26), which drew on an earlier portion of the same survey. Slightly more than half the plants fail to deploy the complete technical system and only 5.4 per cent reach the deepest level, which is what makes the penalised estimation described in Section 2.4 necessary.

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Table 1. Distribution of technical-system maturity by sector (n = 316).

Sector	n	Partial	Basic	Integral	Deep
Automotive	157	48.4 %	33.1 %	11.5 %	7.0 %
Electrical/electronics	67	47.8 %	40.3 %	10.4 %	1.5 %
Aerospace	49	63.3 %	26.5 %	6.1 %	4.1 %
Medical devices	43	62.8 %	20.9 %	9.3 %	7.0 %
Total	316	52.5 %	32.0 %	10.1 %	5.4 %

The maturity gradient

High operational performance was attained by 121 of the 316 plants (38.3 per cent). The two clusters separate cleanly on the five hard improvement indicators rather than on declared satisfaction, and the partition agrees with a simple median split on 92.7 per cent of cases and with an upper-tercile split on 97.2 per cent, indicating that it is not an artefact of the algorithm.

Figure 2 presents the central result. The proportion of plants attaining high operational performance rises monotonically across the four maturity levels, without exception: 21.7 per cent of the 166 Partial plants, 46.5 per cent of the 101 Basic, 71.9 per cent of the 32 Integral and 88.2 per cent of the 17 Deep. The trend test yields an odds ratio of 3.00 per level ($z = 6.63$, $p < 0.001$), and the ordinal association between maturity and the continuous performance score is substantial (Spearman rho = 0.512, $p < 0.001$). H1 and H2 are supported.

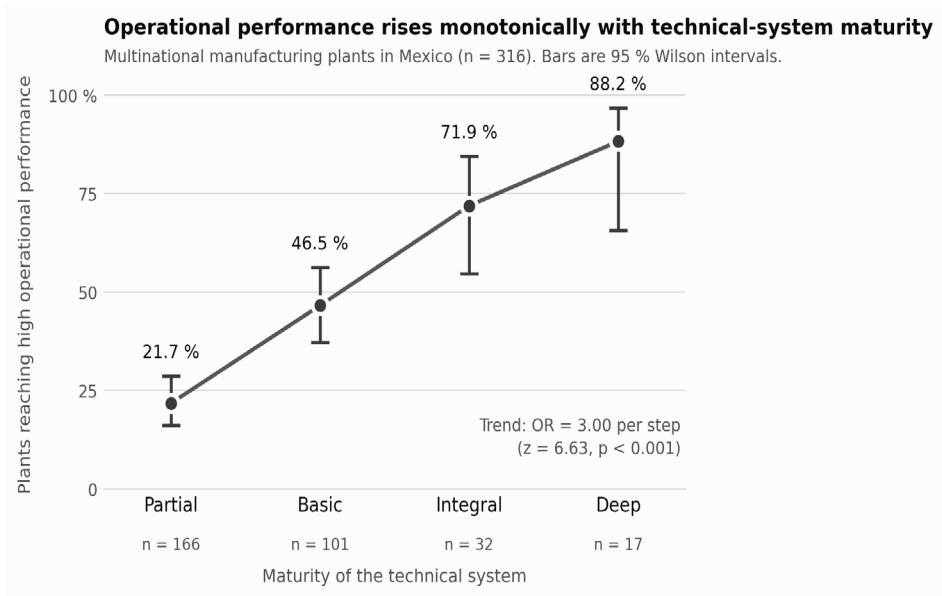

Figure 2. Proportion of plants attaining high operational performance by level of technical-system maturity, with 95 per cent Wilson intervals (n = 316).

Adjusted models

Table 2 reports the penalised logistic regressions. In the level model, each maturity level is compared with Partial after adjustment for programme age and plant size: the odds of high operational performance are 2.96 times higher for Basic plants, 8.24 times higher for Integral

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plants and 20.29 times higher for Deep plants, all with $p < 0.001$. The gradient is preserved and the ordering of the point estimates matches the unadjusted profile. H3 is supported.

Table 2. Firth penalised logistic regression predicting high operational performance (n = 316).

Predictor	OR	95 % CI	p
Level model (reference: Partial)			
Basic	2.96	1.72 – 5.13	< 0.001
Integral	8.24	3.62 – 20.12	< 0.001
Deep	20.29	5.86 – 106.44	< 0.001
Programme age (per step)	1.08	0.89 – 1.32	0.432
Plant size (per step)	0.98	0.76 – 1.27	0.876
Dichotomous model: complete system	4.34	2.65 – 7.22	< 0.001
Fully adjusted model: deep maturity	9.84	2.94 – 50.60	< 0.001
Programme age (per step)	1.20	1.00 – 1.45	0.051
Plant size (per step)	1.01	0.79 – 1.30	0.945
Automotive (ref.: aerospace)	1.31	0.65 – 2.75	0.453
Electrical/electronics	1.27	0.57 – 2.90	0.565
Medical devices	1.59	0.65 – 3.93	0.310

Three secondary results deserve attention. First, no sector contrast approaches significance, and the automotive sector – conventionally assumed to be the most advanced – is indistinguishable from the rest once maturity is held constant. Second, plant size is null throughout (OR ≈ 1.00). Third, programme age carries no independent effect in the level model (OR = 1.08, $p = 0.432$) and is at best marginal in the fully adjusted one (OR = 1.20, $p = 0.051$), which indicates that elapsed time operates through the maturity attained rather than alongside it.

Robustness

Six checks were performed. Comparing Firth estimates with unpenalised maximum likelihood, the two agree within 2.2 and 4.4 per cent where cell counts are adequate and diverge by 18.3 per cent where the smallest cell contains two observations, confirming that the correction operates only where it should. Across four alternative definitions of high operational performance, the odds ratio for the complete-system predictor ranges between 4.16 and 7.97 with unchanged direction. Raising the maturity threshold produces a dose-response in the measure itself (OR 4.34, 6.72 and 10.16 for the successive thresholds). Excluding two exactly duplicated records leaves the estimates essentially unchanged (OR 4.25, 6.51 and 9.55).

A further comparison bears on the measurement argument. Grouping the twelve practices into three bundles by their position in the House of the TPS – workplace-organisation base, flow pillar and intermediate practices – each bundle predicts performance on its own with similar discrimination (AUC 0.735 to 0.770). When entered jointly, however, the base bundle loses significance (OR 1.42, $p = 0.107$) while the flow and intermediate bundles retain it (OR 1.52, $p = 0.032$; OR 1.71, $p = 0.012$). Because the bundles are strongly intercorrelated ($r = 0.68$ to 0.75), this decomposition should be read as indicative rather than conclusive; it is reported because it bears directly on why a conjunctive measure may discriminate where an average does not.

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A fifth check addresses common method variance. In the unrotated principal-component solution over the nineteen items the first component accounts for 43.6 per cent of the variance, below the conventional criterion, and three components exceed unit eigenvalue; the performance items load more strongly on the second component than on the first, so predictor and outcome do not collapse into a single factor. Correlations between the practice and the performance blocks (median r = 0.357) are lower than those within either block (0.436 and 0.429), which is the reverse of the pattern a dominant method factor produces. The marker variable correlates with the nineteen items at a median absolute value of 0.039, giving r_M = 0.022; the marker-adjusted correlation between maturity and performance falls from 0.418 to 0.405 and remains significant ($p < 0.001$), and entering the marker in the trend model moves the odds ratio by at most 4.7 per cent.

A sixth check bears on the symmetry the measure assumes. Estimating the response of performance to each practice separately yields odds ratios between 1.51 and 2.25 per level of coverage, every one of them significant at $p < 0.001$. A test of homogeneity across the twelve slopes does not reject a common value ($Q = 11.95$, $df = 11$, $p = 0.368$; I-squared = 7.9 per cent), the pooled estimate being 1.78 per level of coverage. The twelve practices therefore contribute with indistinguishable intensity, which is the empirical condition under which applying one threshold to all of them simultaneously is a defensible operation rather than a convention; it also reproduces, in a different manufacturing network, the finding that the principles of a programme behave alike (4). This does not contradict the bundle decomposition reported above: a practice may carry the same odds ratio per level of coverage and still discriminate weakly within a given sample, because discrimination requires variation as well as slope, and the most widely deployed practices have little variation left. Equal intensity and unequal discriminating power are properties of different things, the coefficient and the distribution. Two features qualify the result. Deployment rises with programme age and decelerates in all twelve practices, but the sample contains no plant at the beginning of deployment, so only the upper portion of that trajectory is observed. And for the most widely deployed practices the low-coverage cells are very small, so the flat start of those curves rests on few observations.

Discussion

Generality of the association across firms (H1)

The maturity–performance proposition survives the move out of the single corporation. Across 316 plants belonging to different multinationals, running different corporate programmes, in four sectors and one emerging economy, the probability of attaining high operational performance rises monotonically with the maturity of the technical system, and the gradient withstands adjustment for programme age, plant size and sector. This extends the S-curve finding (4) in the direction that mattered most for its generality: the association is not an artefact of holding corporate culture, programme content and measurement constant.

The theoretical weight of this result depends on what varies across the sample. The XPS literature describes corporate programmes as variants that share principles with different emphases, the own-best-way pattern identified across thirty multinationals (1), and the resource-based reading

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treats each programme as a firm-specific asset whose value lies partly in being hard to imitate (2). If the performance effect resided in the idiosyncratic content of each programme, the association would weaken when plants running different programmes are pooled. It holds instead, which locates the effect in the technical core that the programmes share with the TPS. The result is consistent with the distinction between adoption and implementation drawn in other settings (5): the plants that perform best are distinguished by how completely they have implemented the technical core of their programme. The association also holds in an emerging economy where, as argued in Section 1, subsidiaries deploy corporate programmes under local resource and capability constraints (7,21). The data cannot show whether those constraints slow deployment, but the gradient indicates that the return to deployment persists under them.

Shape of the response (H2)

The response profile is graded, not threshold-like, which carries a direct managerial implication. Between the Partial and Basic levels alone – that is, simply having started all twelve practices somewhere in the plant – the proportion of high performers more than doubles, from 21.7 to 46.5 per cent. Incremental deployment therefore pays, and the common managerial intuition that lean only rewards those who complete the journey is not supported. It should be noted, however, that the observed profile is concave over the range of the data rather than sigmoid: the flat lower segment predicted by the S-curve is not visible here, which may reflect that the lowest level in this study still contains plants with substantial partial deployment. Resolving the shape at low maturity would require finer measurement at that end.

The profile has a precise form. With an odds ratio of 3.00 per level, a constant multiplicative gain in the odds of high performance reproduces the four observed proportions almost exactly: starting from 21.7 per cent at the Partial level, it predicts 45.4, 71.4 and 88.2 per cent at the following levels, against 46.5, 71.9 and 88.2 per cent observed, and the step-specific odds ratios computed from the observed proportions are 3.14, 2.94 and 2.92. The relationship is therefore close to linear on the log-odds scale over the observed range, and the concavity visible in Figure 2 is the compression that a constant odds ratio produces as probabilities approach one. Read through the two dimensions of maturity (4,29), the step from Partial to Basic is an increase in breadth, since it completes the set of practices, and the two subsequent steps are increases in depth. Each step multiplies the odds by a similar factor, so breadth and depth contribute comparably to performance over this range and the conjunctive measure captures both. For plants operating under resource constraints the first step has a particular reading: it requires only that every practice be present somewhere in the plant, and it raises the proportion of high performers by about 25 percentage points, a gain comparable to that of the next step and larger than that of the last.

Contextual attributes and programme age (H3)

Three null results are informative. Sector does not discriminate, which extends an established result rather than announcing a new one: adoption of lean practices in this population had already been shown not to depend on industry sector (26), and the present analysis shows that the outcome of that adoption does not depend on it either. The automotive advantage that the

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Mexican manufacturing literature routinely assumes turns out, once maturity is controlled, to be an advantage of maturity and not of sector. Plant size does not discriminate either, which contradicts a persistent contextual explanation of performance differences (6,38). And programme age loses its independent effect, which refines rather than contradicts the existing account: time does not buy performance, it buys maturity, and maturity buys performance. This pattern is consistent with a mediation structure in which elapsed time acts through the maturity it allows a plant to reach; the design does not test that mediation formally, but the pattern explains why elapsed time has repeatedly proved an unsatisfactory proxy (4).

These null results bear on the contingency explanations reviewed in Section 1. Plant size (6), the development level of the host country (7) and organisational culture (8) have each been proposed as reasons why plants differ in performance. The present design holds the host country constant and does not measure culture, so it cannot evaluate those two attributes; it does test size and sector, and neither displaces maturity. Within a single emerging economy, the contextual attributes observable at plant level therefore explain less of the difference in performance than the extent to which the technical system has been deployed. Context may still shape how fast a plant matures, which is a question about the antecedents of maturity that this study leaves open.

Empirical, theoretical and methodological contributions

The findings support three contributions, each defined by what it adds to the literature reviewed in Section 1. The empirical contribution is the extension of the maturity–performance proposition beyond the single corporation in which it was established (4). Before this study the proposition rested on plants that shared one programme, one corporate culture and one measurement system; it now rests also on plants that share none of these, in an emerging economy and, to the best of the author's knowledge, for the first time in a Mexican setting. The extension matters because managers of plants outside the corporations studied can only rely on the cross-firm version of the proposition, and that version had not been tested.

The theoretical contribution concerns the form of the proposition. The S-curve account (4) predicts flat segments at both ends of the maturity range, which would make partial deployment unrewarding at low levels. Over the range observed here, the response is graded and close to constant in log-odds, and programme age loses its independent effect once maturity is controlled. Together, these results specify the proposition more precisely: performance responds to how far deployment has advanced, by a similar factor at each step, and time contributes to performance through the maturity it allows a plant to reach. These data do not support a theory of maturity that treats partial deployment as a transitional state without returns.

The methodological contribution concerns measurement and is the one most likely to transfer to other studies. A conjunctive maturity measure – one requiring all twelve practices to clear the same threshold – discriminates clearly, and the bundle decomposition suggests why: the practices that are most widely deployed are the least able to distinguish high from low performers, precisely because they are nearly universal. An average across practices would let those abundant practices dominate the composite and mask the absence of the rare ones. This is consistent with

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the sociotechnical reading of lean, in which effects arise from interaction among the parts rather than from their sum (12,13), and it suggests that the widespread practice of building lean scores as averages (6,11,39) may systematically understate the maturity–performance relationship. The contribution lies in establishing the functional form of a maturity measure as a substantive choice: the conjunctive form follows from the definition of breadth (Section 1.1.2), and the homogeneity of slopes reported in Section 3.4 supplies the empirical condition that justifies applying one threshold to all practices. A direct comparison between the conjunctive measure and an average-based index on the same data was not performed and remains for further work.

Corroborating evidence and implications for multi-plant programmes

The direction of the association is corroborated by recent plant-level evidence. Studies in packaging, precast concrete and general manufacturing report operational gains that follow the deployment of the same practice set (40,41,42), and analyses that model the path from lean strategy to performance find it mediated rather than direct (39,43). Two qualifications from that literature bear on the present result. Organisational culture and agility condition how far a technical programme translates into performance (44), and the integration of digital technologies is reshaping what deployment means in practice (45,46). Neither is measured here, and both are reasons to read the estimated association as conditional on a context this design holds fixed.

For the management of multi-plant programmes, the results locate the binding constraint. The literature has long noted the tension between global conformity and local autonomy in corporate improvement programmes (15,29). The present findings indicate where that tension is concentrated: in the practices that a plant cannot resolve within the boundaries of a single work area. Corporate resources appear to yield more when concentrated there than when distributed evenly across the whole practice set.

Limitations

Six limitations qualify these findings; the first four follow from the design choices justified in Section 2.1 and are restated here for their bearing on interpretation. The design is cross-sectional, so the association cannot be read causally; the direction from maturity to performance is theoretically motivated (4) but not established here. Predictor and outcome come from the same informant and the same instrument, which raises common method variance (47); the diagnostics reported in Section 3.4 do not detect a dominant method factor, and the behavioural nature of the coverage scale, which asks what proportion of the plant a practice covers rather than how good it is, further limits the risk, but a single-informant design cannot eliminate it. The sample is non-probabilistic and drawn from four sectors of multinational manufacturing in Mexico, so the proportions should not be extrapolated to the wider manufacturing base. Because some firms contribute more than one plant, observations from the same firm may share unmeasured corporate influences, such as programme content, headquarters support or internal audits. The dependence is limited in the variable of interest, because plants running the same corporate programme can differ widely in maturity (4), and it bears mainly on the precision of the estimates. Firm identifiers were removed before analysis to preserve anonymity, so the dependence could not be modelled with firm-

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clustered errors, and the reported confidence intervals may be somewhat narrower than such a correction would produce. The trend test (z = 6.63) would nevertheless remain significant at the 5 per cent level unless clustering inflated its standard error more than threefold. The outcome side is incomplete in one specific respect: total productive maintenance is among the twelve practices measured, but only its deployment coverage is recorded, and the proximate outcomes through which it is expected to act – equipment reliability, maintainability and availability, and the overall equipment effectiveness that summarises them – were not measured, so the mechanism that links maintenance practice to plant performance is not observed here (14,48,49,50,51). Finally, the study covers only the technical subsystem of the XPS; the social subsystem, which the literature identifies as the part where XPS models diverge most from the TPS (1), is outside its scope.

Conclusions

The study asked whether the maturity of the technical system of XPS models predicts high operational performance when the comparison is made across firms, corporate programmes and sectors, and whether the association is graded or threshold-like. The evidence from multinational plants in Mexico answers both parts of the question. Maturity is associated with high performance across firms (H1); the association grows step by step across the four levels of maturity, with no threshold below which deployment yields nothing (H2); and it persists when programme age, plant size and sector are held constant (H3).

Taken together, the three results change what can be inferred from the state of a corporate programme. Having adopted an XPS, belonging to the automotive sector, running a large plant or having started the programme many years ago do not by themselves indicate that a plant will perform well. What indicates it is the completeness with which the twelve technical practices are deployed, and every step towards completeness is associated with better results. For subsidiaries in emerging economies, where the resources for deployment are limited and allocated by the plant itself, partial progress can therefore be justified on its own terms. Because maturity was measured conjunctively, the results also suggest that progress counts when it extends to every practice, including those not yet widespread, although only a longitudinal design could establish this as a deployment rule.

The answer is bounded by the design. Because the data are cross-sectional and come from one informant per plant, the study establishes the existence and shape of the association but not its direction, and the lower end of the response curve, where the S-curve account predicts a flat segment, lies outside the observed range.

Three lines of continuation follow directly. A longitudinal design would establish the direction of the association and permit observation of the lower segment of the response curve. Extending the measurement to the social subsystem would test whether its deployment follows an order of its own or accompanies that of the technical system. And replication in other emerging manufacturing economies would establish whether the null result for sector and size is a feature of the Mexican multinational plant population or a general one.

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Declarations

Ethics. The study involved a voluntary, anonymous survey of professionals reporting on organisational practices at their plant. No personal, sensitive or identifying data were collected and no intervention took place; participation implied informed consent, and plant and company identifiers were removed before analysis.

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Use of artificial intelligence. Generative AI tools were used only to assist with language editing and improving the clarity of the manuscript. No AI tool was used to generate data, perform statistical analyses, interpret findings, or determine the scientific content or conclusions of the study. The author critically reviewed and approved all AI-assisted revisions and remains fully responsible for the manuscript.

Conflict of interest. The author declares no conflict of interest in the development or publication of this research.

Data availability. The data supporting the findings are available from the author on reasonable request, in anonymised form and without identification of the participating plants.

Related work. The data derive from a single survey of multinational manufacturing plants in Mexico, from which studies differentiated by research question and subsample are drawn. A previous study, already published (26), drew on an earlier portion of this survey, whose data collection continued afterwards; it describes which lean practices are adopted, distinguishes partial from integral adoption, and reports that adoption does not differ significantly across industry sectors; it contains no measure of operational performance and no inferential model. The present study introduces operational performance as a dependent variable, defines a four-level maturity measure, and tests whether maturity predicts performance. It reports no descriptive result already published.

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