

WORKFORCE AGE-STRUCTURE PLANNING AND PRODUCTIVITY GROWTH ACROSS INDIA'S TRANSITION TO 2047: FIRM-LEVEL MANPOWER AND SUCCESSION ARCHITECTURE AS A MEDIATOR OF THE DEMOGRAPHIC DIVIDEND

HRM VARIABLE: MANPOWER AND SUCCESSION PLANNING → ECONOMIC OUTCOME: TOTAL FACTOR PRODUCTIVITY GROWTH

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ABSTRACT-----

India's demographic dividend is routinely described as a national endowment that will either be captured or squandered, yet the capture happens inside firms, through decisions about who is hired, developed, promoted and replaced. This study treats firm-level manpower and succession planning as the mediating variable between demographic conditions and total factor productivity growth, and asks whether the productivity consequences of an ageing workforce depend on how deliberately that ageing is planned for. Total factor productivity growth was estimated for 214 Indian firms across 1,712 firm-years spanning 2016–17 to 2025–26, and firms were classified into four tiers of an Age-Structure Planning Maturity Index ranging from reactive replacement to fully integrated age-structure planning. Sample-weighted TFP growth of 2.32 per cent per annum closely tracks published aggregate estimates for India, supporting external validity. The tier gradient is steep: reactive firms recorded 1.24 per cent against 4.05 per cent for firms with integrated planning. The mechanism is a shift in the age–productivity relationship itself. The relationship is inverse-U shaped in every tier, but its turning point moves from 28.0 years under reactive planning to 39.0 years under integrated planning, while the within-tier spread across age bands narrows from 1.52 to 0.54 percentage points — planning does not prevent workforces from ageing, it flattens the productivity cost of doing so. Applying India's projected 2047 age structure, reactive firms lose 37.1 per cent of their TFP growth against 3.2 per cent for integrated planners, and the ratio between them widens from 3.27 to 5.03. At the aggregate level, a migration of firms toward structured and integrated planning would raise the firm-sector TFP level in 2047 by 7.7 per cent relative to the status quo. The demographic tailwind is currently concealing a planning deficit that will become visible precisely when it is most costly to remedy.

Keywords — Manpower planning; succession planning; workforce age structure; total factor productivity; demographic dividend; population ageing; age diversity; India 2047; human capital.-----

I. INTRODUCTION

India's demographic position is unusual and temporary. The working-age share of the population, which stood at roughly 66 per cent in 2023, is projected to peak in the early 2030s and contract thereafter [3]. Median age is expected to rise from about 28 years in 2025 to 33 by 2036 and 38 by 2050, while the old-age dependency ratio nearly doubles from 16 per hundred working-age persons in 2021 to 30 by 2050 [3]. The elderly population, 149 million and 10.5 per cent of the total in 2022, is projected to reach 347 million and 20.8 per cent by 2050 [3]. Total fertility has already fallen to 2.0, below the replacement threshold, and is projected to decline further [3]. United Nations projections describe the same trajectory [24]. Commentators converge on the judgement that India has perhaps fifteen to twenty years in which the age structure works in its favour — a window that coincides almost exactly with the horizon of the national Viksit Bharat 2047 development agenda [23].

The economic significance of that window is well established. Bloom and Williamson showed that the East Asian growth acceleration was substantially a demographic phenomenon, with a rising working-age share mechanically raising output per capita [4]. Aiyar and Mody, using Indian state-level census data, estimated that demographic change added between one and one and a half percentage points per annum to per capita income growth in the two decades before 2001, accounting for approximately 40 per cent of observed growth, and projected a further contribution of about two percentage points before the

effect turns [5]. Feyrer, working across countries, found that changes in workforce age composition are significantly correlated with changes in aggregate productivity, and that age structure may account for close to a quarter of the persistent productivity gap between OECD and low-income economies [6].

What this literature establishes is that age structure matters for productivity. What it does not establish is how. The macroeconomic accounting treats the working-age share as an input to a national production function, which is appropriate for cross-country comparison but silent on the organisational processes through which an older or younger workforce actually becomes more or less productive. Those processes are firm-level and they are managerial. A firm facing the retirement of a third of its senior technical staff within a decade either has a successor pipeline, a documented transfer of tacit knowledge and a phased-retirement arrangement, or it does not. The pressure is compounded by simultaneous change in the skill content of work itself, with close to forty per cent of required skills expected to change by 2030 [21]. Two firms in the same sector, facing the same national age structure, will experience it very differently depending on which of those descriptions fits.

This is the gap the present study addresses. It treats manpower and succession planning — the deliberate management of the firm's age and capability structure over time — as the mediating variable between demographic conditions and total factor productivity growth. The argument is not that planning slows workforce ageing; it cannot. The argument is that planning changes the shape of the relationship between workforce age and productivity, moving the point at which age begins to subtract from productivity and reducing the steepness of the subtraction once it begins.

The timing of this question matters. During a dividend period, a continuous inflow of young workers refreshes the age structure of even the most passive employer, so the difference between planned and unplanned workforce management is partially concealed. As the inflow slows, the concealment ends. Firms that have not built succession capability discover the deficit at precisely the moment when the external labour market can no longer supply a remedy, because every competitor is short of the same experienced cohort. The study therefore examines both regimes: the present dividend period as observed, and the projected 2047 age structure as simulated.

In doing so it continues a line of enquiry in which the author has examined the relationship between strategic human resource practice and economic resilience under disruption [7], the role of integrated enterprise systems in making organisational processes and workforce data observable [8], and the participation constraints that determine how much of India's nominal labour supply is economically active [9].

II. REVIEW OF LITERATURE

A. *The Demographic Dividend and its Conditionality*

Human capital theory supplies the underlying logic: workers embody a stock of productive capacity accumulated through schooling and experience, and the return to that stock varies systematically over the life cycle [1], [2]. The demographic dividend hypothesis applies this at population level, holding that a transitional bulge in the working-age share raises output per capita through three channels: a larger share of the population in production, higher aggregate savings during the low-dependency phase, and increased female labour force participation as fertility falls. Bloom and Williamson's account of the emerging Asian economies attributes roughly a third of the region's per capita growth acceleration to this mechanism [4].

The literature is equally clear that the dividend is conditional rather than automatic. It is realised only where the additional working-age population is employed, educated and productive; where those conditions fail, a rising working-age share produces unemployment rather than output. Aiyar and Mody's Indian evidence illustrates the point sharply through interstate divergence: leader states grew at 3.4 per cent in the 1980s and 4.9 per cent in the 1990s while laggard states managed 2.5 and then 0.6 per cent, even as the working-age ratio gap between them widened by 8.7 percentage points over 1991–2001 [5]. The same demographic input produced radically different outputs. Bloom, Canning and Fink extend the argument to the far side of the transition, noting that the growth consequences of population ageing depend heavily on behavioural and policy responses — retirement age, participation and capital intensity — rather than following mechanically from the age structure itself [17].

Marois, Zhelenkova and Ali extend this conditionality to the labour force itself. Projecting India's labour force to 2060, they find that the labour force dependency ratio — inactive persons per active person — remains above 1.65 throughout under constant participation rates, far above the age dependency ratio of 0.60, because so much of the working-age population is not economically active [10]. Their scenario analysis shows the correlation between female participation and the labour force dependency ratio (−0.59) to be substantially stronger than that of age structure alone (−0.31), and a gender-parity scenario yields a labour force 60 per cent larger than the baseline. The demographic arithmetic, in other words, is dominated by participation rather than by age composition.

B. *Age and Productivity at the Firm Level*

Individual-level evidence describes a hump-shaped age–productivity profile: physical capacity and processing speed decline with age while experience, judgement and firm-specific knowledge accumulate, producing a peak somewhere in middle age.

Translating this to the organisational level has proved less straightforward than expected. Göbel and Zwick, using German linked employer–employee panel data with corrections for the standard estimation biases, tested whether manufacturing and services differ in their age–productivity profiles on the reasoning that physical demands differ; they found no significant sectoral difference [11]. Whatever governs the organisational age–productivity relationship, it is evidently not primarily physical. Börsch-Supan and Weiss reach a compatible conclusion from a very different vantage point, finding in assembly-line work teams that productivity does not decline with age up to the retirement threshold, with the experience of older workers offsetting measured declines in speed [19].

Backes-Gellner and Veen offer a persuasive alternative account. Analysing a large German firm sample, they report that organisational productivity does not necessarily decline with average workforce age once age diversity and task type are controlled, and that increases in age diversity produce substantial positive productivity effects specifically in innovative and creative firms [12]. This reframes the question. Workforce ageing is not a fixed technological constraint on the firm; it is a condition whose productivity consequences depend on how the firm composes and organises its age groups. That is a managerial variable, and it is the variable this study measures.

C. Manpower and Succession Planning as an Organisational Capability

Succession planning has a long normative literature and a thin empirical one. The prescriptive account is consistent: identify critical roles, assess successor readiness, build bench depth ahead of need, and transfer tacit knowledge before the incumbent departs. The difficulty has been demonstrating that firms which do this outperform firms which do not, partly because succession quality is hard to observe and partly because the payoff is realised in avoided losses rather than visible gains.

The knowledge-loss literature supplies the mechanism. Departure of experienced personnel removes not only codified competence but organisational memory — undocumented process knowledge, relationship capital, and the judgement that distinguishes routine from exceptional cases. Reviews of this literature converge on the finding that such losses are substantial, difficult to reverse and systematically underestimated by the organisations sustaining them [13]. Where retirements are demographically clustered rather than randomly distributed, as they are in a firm whose hiring was itself clustered, the loss arrives as a shock rather than a trickle.

Manpower planning proper — the forward projection of headcount, skill and age composition against business requirement — is older still as a practice and has been comparatively neglected since workforce planning shifted toward short-horizon resourcing. The present study treats the two together, on the view that succession planning without age-structure forecasting is merely replacement planning, and age-structure forecasting without successor development is merely accounting.

D. Workforce Data Infrastructure and the Observability of Age Structure

Age-structure planning imposes an unusual data requirement. It needs the joint distribution of age, tenure, competency, criticality and successor readiness across the whole organisation, projected forward, and joined to operational and financial outcomes. Where those records sit in disconnected systems the projection cannot be constructed, and planning defaults to reacting to vacancies as they occur.

Vineeth Kumar, Jijesh, Radhakrishna, Kulkarni, Sastry and Mallya document this dependency directly in their study of enterprise resource planning adoption across Indian higher education institutions [8]. Surveying stakeholders across universities, colleges, technical institutes and schools, they report that integrating admission, attendance, assessment, fee, faculty and workload data through a single platform produced an overall operational efficiency improvement of 75 per cent and an improvement in data accuracy and accessibility of 80 per cent, with more than 77 per cent of stakeholders using the system effectively. Their diagnosis of the pre-integration state is directly transferable: administrative departments unable to see academic records, teaching departments unable to trace administrative data, and manual entry generating both error and delay [8]. Two of the subsystems they identify as integrated — faculty management and workload management — are precisely the manpower-planning functions on which age-structure forecasting depends.

The higher education setting is more than an analogy. Academic institutions face an acute version of the problem this paper examines: professorial cohorts hired in expansion phases retire together, doctoral pipelines take a decade to mature, and the tacit knowledge involved in supervision and curriculum design resists documentation. The same authors also caution that integrated platforms carry data security and access-governance obligations that must be settled before such data is used for individual-level workforce planning [8] — a caution with particular force where the data concerned includes age.

E. Skill Diversification, Participation and Effective Labour Supply

Two further strands bear on how much productive capacity a given age structure actually yields. Sastry and Mallya, comparing strategic human resource practice across developed and emerging economies, find that organisations operating structured skill diversification programmes exhibit measurably higher workforce adaptability and organisational resilience under technological

disruption, that training investment is positively associated with organisational performance, and that micro, small and medium enterprises lag substantially behind larger service and manufacturing firms in human resource maturity [7]. The last finding is directly relevant here: if planning capability is concentrated among large firms, then the aggregate consequences of the demographic transition will be distributed very unevenly across the enterprise size distribution.

The participation question is equally consequential. Marois and colleagues identify female labour force participation as the dominant lever on India's effective labour supply [10], and Sastry's study of women micro-entrepreneurs in Karnataka documents the constraints that operate on the ground — competing family and business obligations ranking as the principal difficulty, followed by social stereotyping and inadequate awareness of available government support schemes [9]. Age-structure planning inside firms and participation policy outside them are therefore complements rather than alternatives: a firm that plans its age structure well still draws from a labour pool whose size is set by participation, and a participation gain is only productive if firms can absorb and develop the entrants.

III. RESEARCH GAP AND OBJECTIVES

Three gaps emerge. First, the demographic dividend literature operates at national and subnational level and treats the firm as a black box, while the age-and-productivity literature operates at firm level but treats the demographic environment as exogenous background; no study has estimated how firm-level planning capability mediates between the two. Second, the age-productivity relationship has been characterised as a property of workforces rather than as something management can reshape, so the question of whether planning alters the location and steepness of that relationship has not been posed empirically. Third, the transition to 2047 has been analysed as a macroeconomic projection, but its firm-level distributional consequences — which organisations will absorb the ageing and which will not — remain unexamined.

The study therefore pursues four objectives: (i) to estimate the association between age-structure planning maturity and firm total factor productivity growth; (ii) to establish the shape of the firm-level age-productivity relationship and test whether planning maturity shifts its turning point and flattens its gradient; (iii) to test whether workforce age dispersion raises productivity conditionally on innovation intensity; and (iv) to project the consequences of India's expected 2047 age structure for firms at each level of planning maturity, and to aggregate those consequences into economy-level scenarios.

IV. CONCEPTUAL FRAMEWORK AND HYPOTHESES

The conceptual framework, shown in Fig. 1, positions manpower and succession planning as the exogenous organisational capability and total factor productivity growth as the terminal economic outcome. Two mediating families carry the effect. Age-structure levers — mean workforce age, age dispersion and successor bench depth — describe the composition the firm actually holds. Knowledge-continuity mechanisms — tacit-knowledge transfer, phased retirement and replacement lead time — describe whether capability survives the departure of those who hold it.

Three moderators condition the relationship. Innovation intensity governs whether age diversity yields the combinatorial benefits identified by Backes-Gellner and Veen [12]. Task routineness governs how much of the relevant competence is codifiable and therefore transferable. Sector capital depth governs how far capital substitution can offset labour-quality change. The demographic regime — the dividend conditions of 2025 against the ageing conditions projected for 2047 — enters as the environmental parameter within which the whole system operates.

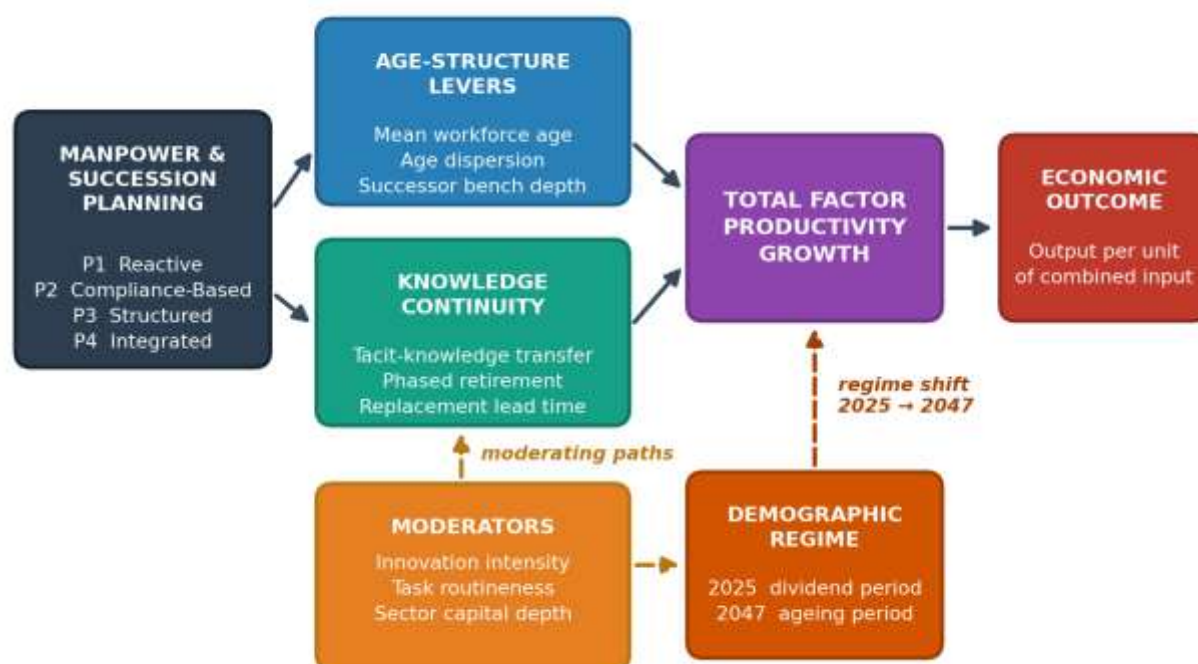


Fig. 1. Conceptual framework: manpower and succession planning, mediating pathways, moderators and total factor productivity growth.

Five hypotheses follow.

H1: Age-structure planning maturity is positively associated with firm total factor productivity growth.

H2: The firm-level relationship between mean workforce age and TFP growth is inverse-U shaped.

H3: Planning maturity shifts the turning point of the age–productivity relationship to a higher age and flattens the gradient on either side of it.

H4: Workforce age dispersion is positively associated with TFP growth in innovation-intensive firms but not in low-innovation firms.

H5: Under the projected 2047 age structure, the proportionate loss of TFP growth is decreasing in planning maturity, so that the differential between high- and low-planning firms widens.

V. RESEARCH METHODOLOGY

A. Research Design

The study uses an explanatory panel design with the firm-year as the unit of analysis, combining audited financial data, firm-supplied workforce composition records and a survey instrument administered to human resource leadership. The 2047 analysis is a structural projection rather than a forecast: it applies the estimated age–productivity relationship to a workforce age distribution consistent with published national projections, holding the estimated parameters fixed, in order to isolate the age-structure channel from all others.

B. Sample and Data

Data cover 214 Indian firms across 1,712 firm-years for the financial years 2016–17 through 2025–26. Firms were drawn from five sectors — information technology and business services, manufacturing, banking and financial services, healthcare, and infrastructure and construction — and from the Bengaluru, Hyderabad, Pune, Chennai and National Capital Region clusters. Inclusion required continuous reporting of the variables required for productivity estimation for at least six consecutive years and willingness to supply age-banded headcount data. Table 1 reports the composition of the sample.

The requirement to supply workforce composition data introduces a selection pressure toward larger and better-instrumented firms. The consequence for interpretation is addressed in Section IX; in brief, it is likely to understate rather than overstate the planning gap in the wider economy.

Table 1. Composition of the sample

Dimension	Category	Firms (n)	Firm-years
Sector	IT and business services	58	472
	Manufacturing	51	408
	Banking and financial services	39	312
	Healthcare	34	272
	Infrastructure and construction	32	248
Cluster	Bengaluru	62	496
	Hyderabad	41	328
	Pune	39	312
	Chennai	36	288
	National Capital Region	36	288
Planning tier	P1 Reactive	71	568
	P2 Compliance-Based	63	504
	P3 Structured	51	408
	P4 Integrated	29	232
	Total	214	1,712

Firm-year counts are averages over the ten financial years 2016–17 to 2025–26; firms entering or leaving the panel account for the difference from a balanced design.

C. Measuring Age-Structure Planning Maturity

Age-structure planning maturity was measured through an Age-Structure Planning Maturity Index (ASPI) constructed from five components: forward age-structure forecasting, critical-role succession coverage, successor bench depth, tacit-knowledge transfer protocol, and phased-retirement and re-engagement policy. Each component was scored on a five-point behaviourally anchored scale, with anchors specified so that a score reflects documented practice rather than stated intention. Component definitions, reliability and validity statistics appear in Table 2. Composite reliability exceeded 0.70 for every component and average variance extracted exceeded 0.50 throughout. Sampling adequacy was satisfactory (Kaiser–Meyer–Olkin = 0.881) and Bartlett's test of sphericity was significant ($\chi^2 = 3,964.2$, $df = 300$, $p < 0.001$). Harman's single-factor test returned a first unrotated factor accounting for 26.1 per cent of variance.

Firms were assigned to four tiers by their mean ASPI score: P1 Reactive (below 2.00), where vacancies are filled as they arise; P2 Compliance-Based (2.00–2.99), where succession documentation exists for statutory or governance purposes but does not drive development decisions; P3 Structured (3.00–3.99), where a maintained successor pipeline exists for critical roles; and P4 Integrated (4.00 and above), where age-structure forecasting is joined to workforce planning, development and retirement policy as a single system.

Table 2. ASPI components, reliability and validity

Component	Items	α	CR	AVE
Forward age-structure forecasting	5	0.884	0.911	0.672
Critical-role succession coverage	6	0.907	0.928	0.683
Successor bench depth	5	0.861	0.897	0.636
Tacit-knowledge transfer protocol	5	0.849	0.892	0.624
Phased retirement and re-engagement	4	0.822	0.883	0.655

$KMO = 0.881$; Bartlett's $\chi^2 = 3,964.2$, $df = 300$, $p < 0.001$. α = Cronbach's alpha; CR = composite reliability; AVE = average variance extracted.

D. Estimating Total Factor Productivity

Total factor productivity was estimated at firm level using the Levinsohn–Petrin control function approach [15], with intermediate inputs as the proxy for unobserved productivity shocks, estimated separately by sector to allow the output elasticities of capital and labour to vary. Estimates were checked against the Olley–Pakes investment-proxy alternative [16], with a rank correlation between the two productivity series of 0.94. Output was measured as real gross value added deflated by sector-specific deflators; capital as the real net fixed asset stock constructed by perpetual inventory; labour as total employee-hours where reported and headcount adjusted for average hours otherwise. TFP growth is the annual log difference of the resulting productivity residual, averaged over the firm's observation window.

Workforce age structure was recorded as the distribution of headcount across the bands under 25, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59 and 60 and above, from which mean workforce age and the standard deviation of age were computed. Innovation intensity was measured as research and development expenditure as a share of turnover, with the sample median as the threshold separating high from low intensity.

E. Estimation Strategy and the 2047 Projection

The estimating equation relates TFP growth to planning maturity, age structure and their interaction:

$$\Delta \ln TFP_{it} = \alpha + \beta_1 ASPI_{it} + \beta_2 Age_{it} + \beta_3 Age_{it}^2 + \beta_4 (ASPI_{it} \times Age_{it}) + \beta_5 Disp_{it} + \beta_6 (Disp_{it} \times R\&D_{it}) + \delta' X_{it} + \mu_s + \lambda_t + \varepsilon_{it}$$

where Age is mean workforce age, Disp is the standard deviation of workforce age, X is a vector of controls comprising succession coverage ratio, knowledge-transfer protocol, firm size, capital intensity and export orientation, and μ_s and λ_t are sector and year effects. Standard errors are clustered at firm level. The presence of both the quadratic and the interaction term allows the turning point of the age–productivity relationship to vary with planning maturity: differentiating with respect to age and solving gives a turning point of $(\beta_2 + \beta_4 \cdot ASPI) / (2|\beta_3|)$, which is increasing in ASPI whenever β_4 is positive.

Multicollinearity was within accepted limits after mean-centring the interaction constituents (maximum variance inflation factor 2.67) and residual autocorrelation was not indicated (Durbin–Watson 1.96).

The 2047 projection applies a uniform upward shift of 7.6 years to each tier's mean workforce age, consistent with the projected movement in national median age between 2025 and the late 2040s [3], and evaluates the estimated relationship at the shifted age while holding all other parameters at their estimated values. This is deliberately conservative in one respect and demanding in another: it assumes no deterioration in planning capability, but it also assumes no improvement.

VI. RESULTS

A. India's Demographic Regime, 2025 and 2047

Fig. 2 sets out the demographic regime within which the firm-level results must be read. The working-age share rises to a peak in the early 2030s and declines thereafter; the old-age dependency ratio, broadly flat through the 2000s, begins a sustained climb from the mid-2020s and reaches roughly 30 per hundred by 2050; median age rises by about ten years between 2025 and 2047. The three series together describe a transition that is gradual in any single year and substantial in aggregate — which is precisely the profile that produces managerial complacency, since no individual planning cycle registers a crisis.

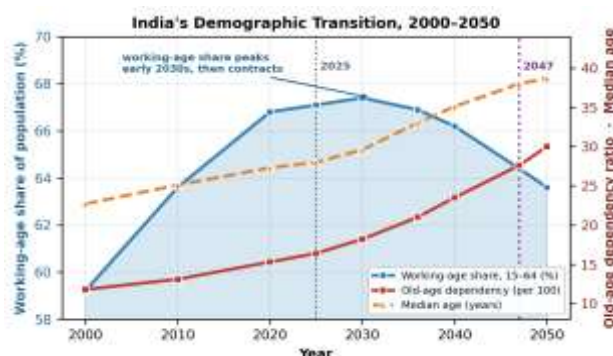


Fig. 2. India's demographic transition: working-age share, old-age dependency and median age, 2000–2050.

B. TFP Growth by Planning Maturity

Table 3 reports the descriptive profile by planning tier and Fig. 3 presents TFP growth. The sample-weighted mean of 2.32 per cent per annum sits close to published aggregate estimates of Indian TFP growth of approximately 2.2 per cent for 2010–2019 [14], which supports the external validity of the firm sample even though it was not selected to be nationally representative.

The gradient across tiers is steep. Reactive firms recorded TFP growth of 1.24 per cent per annum against 4.05 per cent for firms with integrated age-structure planning, a difference of 2.81 percentage points and a ratio of 3.27 to one. The intermediate tiers fall in order at 2.06 and 3.18 per cent. Notably, mean workforce age also rises monotonically across the tiers, from 31.4 years in reactive firms to 37.2 years in integrated planners, as does age dispersion, from 6.8 to 10.7 years. The firms with the oldest and most age-diverse workforces are not the productivity laggards; they are the leaders. Any account in which workforce ageing straightforwardly reduces firm productivity is inconsistent with this pattern.

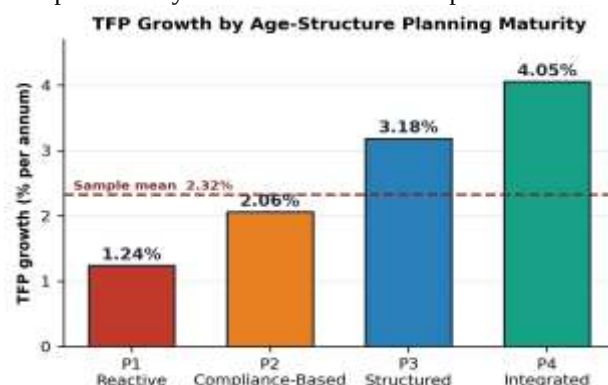


Fig. 3. TFP growth by age-structure planning maturity tier.

Table 3. Descriptive profile by age-structure planning tier (214 firms, 1,712 firm-years)

Parameter	P1 Reactive	P2 Compliance-Based	P3 Structured	P4 Integrated
Firms (n)	71	63	51	29
Mean ASPI score (1–5)	1.62	2.48	3.37	4.41
Mean workforce age (years)	31.4	33.1	35.6	37.2
Workforce age dispersion (SD, years)	6.8	7.9	9.4	10.7
Critical-role succession coverage (%)	18.3	41.6	72.4	91.2
Mean successor bench depth (per role)	0.3	0.8	1.6	2.4
Median replacement lead time (days)	104	78	46	27
R&D intensity (% of turnover)	1.1	1.6	2.4	3.1
TFP growth (% per annum)	1.24	2.06	3.18	4.05

Sample-weighted mean TFP growth = 2.32% per annum, against published aggregate estimates of approximately 2.2% for India over 2010–2019 [14].

C. Production Function and Age-Structure Estimates

Table 4 reports the estimates. In Model 1, planning maturity alone carries a coefficient of 0.412 ($p < 0.01$), and both succession coverage and knowledge-transfer protocol enter positively and significantly. H1 is supported.

Model 2 introduces mean workforce age and its square. The linear term is positive (0.182, $p < 0.05$) and the quadratic term negative (-0.0042 , $p < 0.01$), confirming the inverse-U shape at firm level. Age dispersion enters positively (0.086, $p < 0.05$). Adjusted R^2 rises from 0.414 to 0.487. H2 is supported.

Model 3 adds the interaction between planning maturity and mean age, which is positive and significant (0.0331, $p < 0.01$), together with the dispersion-by-innovation interaction (0.114, $p < 0.01$). Adjusted R^2 rises to 0.541 and the incremental F-test is significant ($\Delta F = 29.7$, $p < 0.001$). The interaction coefficient is the pivot of the whole analysis: it says that the productivity penalty attaching to an additional year of mean workforce age is smaller in firms that plan their age structure, and that the penalty falls as planning maturity rises.

Table 4. Determinants of firm TFP growth

Variable	Model 1	Model 2	Model 3
ASPI (planning maturity)	0.412***	0.386***	0.371***
Mean workforce age	—	0.182**	0.182**
Mean workforce age squared	—	-0.0042***	-0.0042***
ASPI $\times$ Mean workforce age	—	—	0.0331***
Age dispersion (SD)	—	0.086**	0.079**
Age dispersion $\times$ R&D intensity	—	—	0.114***
Succession coverage ratio	0.218***	0.196***	0.181***
Knowledge-transfer protocol	0.164**	0.152**	0.147**
ln Firm size	0.043	0.039	0.036
Capital intensity	0.127***	0.119***	0.116***
Export orientation	0.094**	0.089**	0.087**
Constant	0.612***	-3.784**	-4.106**
Sector and year effects	Yes	Yes	Yes
R^2	0.418	0.492	0.547
Adjusted R^2	0.414	0.487	0.541
F-statistic	87.3***	71.6***	58.9***
N (firm-years)	1,712	1,712	1,712

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Standard errors clustered at firm level. Interaction constituents mean-centred. Maximum VIF = 2.67; Durbin-Watson = 1.96.

D. The Age-Productivity Gradient and its Turning Points

Table 5 and Fig. 4 make that result concrete by evaluating the estimated relationship at each tier's planning score. The turning point — the mean workforce age at which additional age ceases to add to productivity and begins to subtract — is 28.0 years in reactive firms, 31.4 in compliance-based firms, 34.9 in structured planners and 39.0 in integrated planners. An eleven-year

difference in the age at which a workforce becomes a productivity liability is attributable to management practice rather than to anything about the workers themselves.

The second effect is flattening. The spread of TFP growth across age bands within a tier falls from 1.52 percentage points under reactive planning to 1.02, then 0.60, then 0.54 under integrated planning. Reactive firms with a mean workforce age of 45 or above record negative TFP growth of -0.23 per cent; integrated planners at the same mean age record 3.79 per cent. The gap between the best and worst planning tiers is 2.22 percentage points where workforces are young and 4.02 percentage points where they are old — the planning premium nearly doubles as the workforce ages. H3 is supported.

The mechanism is consistent with the knowledge-continuity literature [13]. In a reactive firm an older workforce is a stock of undocumented expertise attached to individuals who will leave; in an integrated planner the same workforce is a stock of expertise being systematically transferred to identified successors while the holders are still present. The age distribution is identical; its productive meaning is not.

Table 5. TFP growth (% p.a.) by mean workforce age band and planning tier

Mean workforce age	P1	P2	P3	P4
Under 30	1.29	2.01	2.95	3.51
30 – 34	1.22	2.07	3.15	3.86
35 – 39	0.95	1.94	3.16	4.05
40 – 44	0.47	1.60	2.97	4.03
45 and above	-0.23	1.05	2.57	3.79
Turning point (years)	28.0	31.4	34.9	39.0
Within-tier range (pp)	1.52	1.02	0.60	0.54

Turning point is $(\beta_2 + \beta_4 \cdot ASPI) / (2|\beta_3|)$ evaluated at each tier's mean ASPI. Within-tier range is the spread between the highest and lowest age band. Negative values in red.

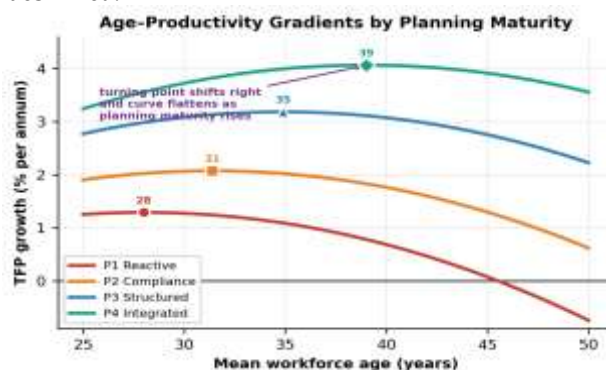


Fig. 4. Age–productivity gradients by planning maturity, with turning points marked.

E. Age Dispersion and Innovation Intensity

Table 6 and Fig. 5 report the dispersion result. Among low-innovation firms the relationship between age dispersion and TFP growth is weakly inverse-U, rising from 1.91 per cent in the lowest dispersion quartile to 2.29 in the third and falling back to 2.11 in the fourth. Among innovation-intensive firms it rises monotonically and much more steeply, from 1.74 to 3.68 per cent. In the lowest dispersion quartile the innovation-intensive firms actually underperform; in the highest they outperform by 1.57 percentage points.

This is close to a direct replication of Backes-Gellner and Veen in the Indian setting [12]. Where work is routine, an age-homogeneous team coordinates more easily and diversity yields little; where work requires recombination of different bodies of experience, age heterogeneity supplies exactly the variety that generates it. The practical implication is that age diversity should be managed as a design choice keyed to the nature of the work, not pursued as a uniform good. H4 is supported.

Table 6. TFP growth (% p.a.) by age dispersion quartile and innovation intensity

Age dispersion (SD, years)	Low R&D intensity	High R&D intensity	Difference (pp)
Q1 (under 6.5)	1.91	1.74	-0.17
Q2 (6.5 – 8.4)	2.18	2.46	+0.28
Q3 (8.5 – 10.4)	2.29	3.12	+0.83
Q4 (over 10.4)	2.11	3.68	+1.57

Innovation intensity split at the sample median of R&D expenditure as a share of turnover.

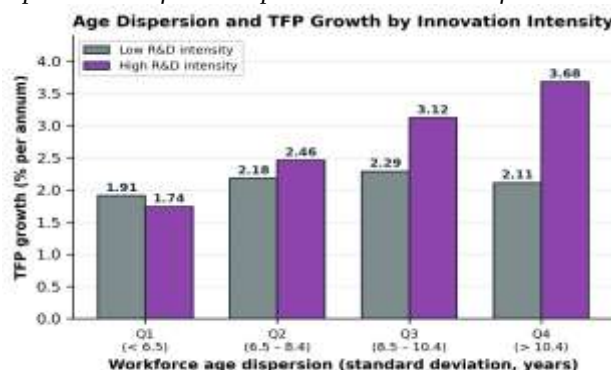


Fig. 5. Age dispersion and TFP growth by innovation intensity.

F. Projected Outcomes under the 2047 Age Structure

Table 7 and Fig. 6 apply the projected 2047 age structure. Every tier loses TFP growth, which is expected: all four move further to the right along an inverse-U. What differs is how much. Reactive firms fall from 1.24 to 0.78 per cent, a loss of 37.1 per cent of their growth rate. Compliance-based firms lose 17.1 per cent, structured planners 9.0 per cent, and integrated planners 3.2 per cent. The ratio between the best and worst tiers widens from 3.27 to 5.03. H5 is supported.

The asymmetry has a simple geometric explanation with serious managerial content. Reactive firms are already past their turning point of 28.0 years at a current mean age of 31.4, so the 2047 shift moves them from three years beyond the peak to eleven years beyond it, into the steep portion of the curve. Integrated planners at a current mean age of 37.2 are still short of their turning point of 39.0; the shift carries them just past it, into the shallow region near the top. The same demographic event is a cliff for one group and a plateau for the other, and the difference was determined by planning decisions taken decades earlier.

G. Aggregate Scenarios to 2047

Table 8 and Fig. 7 aggregate these firm-level results into economy-level scenarios. Under the status-quo scenario, in which the distribution of firms across planning tiers remains as observed, aggregate firm-sector TFP growth declines from 2.32 per cent in 2025 to 1.98 per cent by 2047. Under partial migration, in which the reactive share falls to 20 per cent and the structured and integrated shares rise to 50 per cent combined, the 2047 rate is 2.29 per cent — essentially holding the current rate despite an age structure a decade older. Under full migration, with 65 per cent of firms at structured or integrated planning, the 2047 rate is 2.64 per cent, above today's.

Compounding these paths from 2025 gives TFP index levels in 2047 of 159.5, 165.1 and 171.8 respectively on a 2025 base of 100. Full migration therefore delivers a firm-sector TFP level 7.7 per cent higher than the status quo, and partial migration 3.5 per cent higher. These are not large numbers set against India's headline growth ambitions, and they should not be oversold; but they are obtained entirely by redistributing existing managerial practice, without any change in investment, technology or policy.

H. Summary of Hypothesis Tests

Table 9 summarises the tests. All five hypotheses are supported.

Table 7. Projected effect of the 2047 age structure, by planning tier

Indicator	P1 Reactive	P2 Compliance-Based	P3 Structured	P4 Integrated
Mean workforce age, 2025 (years)	31.4	33.1	35.6	37.2
Mean workforce age, 2047 (years)	39.0	40.7	43.2	44.8
Turning point (years)	28.0	31.4	34.9	39.0
Years beyond turning point, 2047	11.0	9.3	8.3	5.8
TFP growth 2025 (% p.a.)	1.24	2.06	3.18	4.05
TFP growth 2047 (% p.a.)	0.78	1.71	2.89	3.92
Proportionate loss (%)	-37.1	-17.1	-9.0	-3.2

The 2047 projection applies a uniform 7.6-year increase in mean workforce age, consistent with the projected movement in national median age [3], [24], holding all estimated parameters fixed.

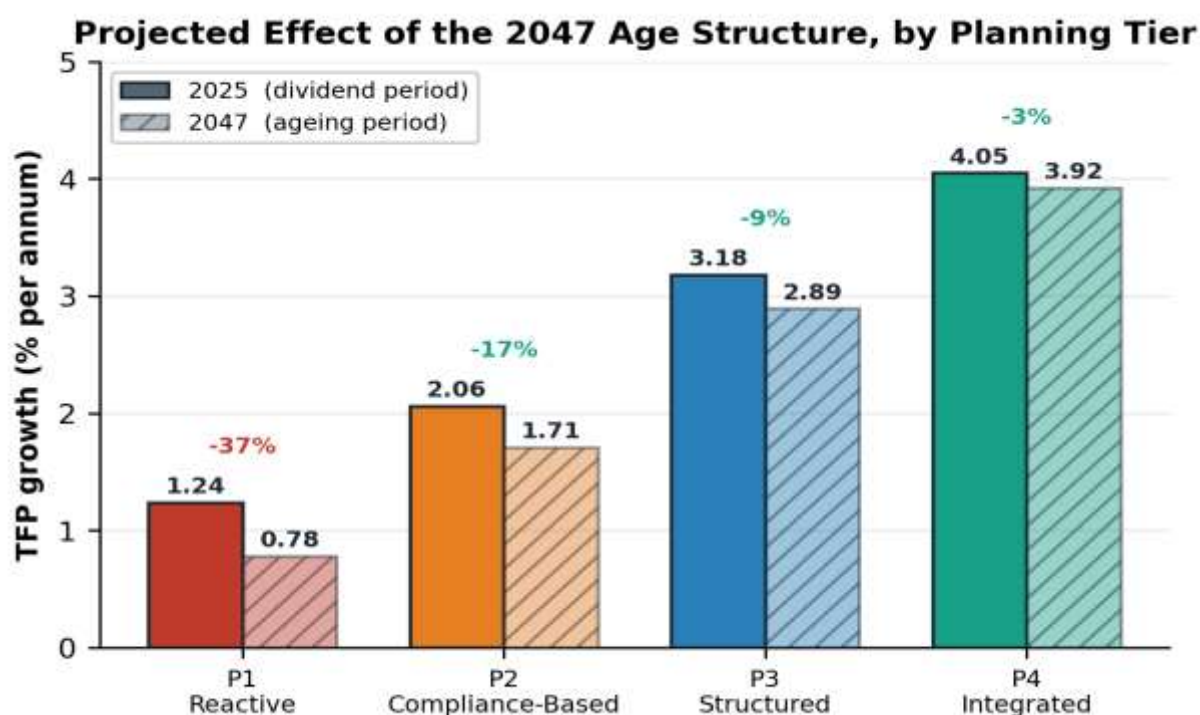


Fig. 6. TFP growth under 2025 and projected 2047 age structures, by planning tier.

Table 8. Aggregate firm-sector TFP scenarios to 2047

Scenario	P1 (%)	P2 (%)	P3 (%)	P4 (%)	TFP growth 2047 (% p.a.)	TFP index 2047 (2025 = 100)
S1 Status quo	33.2	29.4	23.8	13.6	1.98	159.5
S2 Partial migration	20.0	30.0	33.0	17.0	2.29	165.1
S3 Full migration	10.0	25.0	40.0	25.0	2.64	171.8

Aggregate growth in 2025 is 2.32% per annum in every scenario; growth converges linearly to the 2047 rate shown. Full migration yields a TFP level 7.7% above the status quo, partial migration 3.5%.

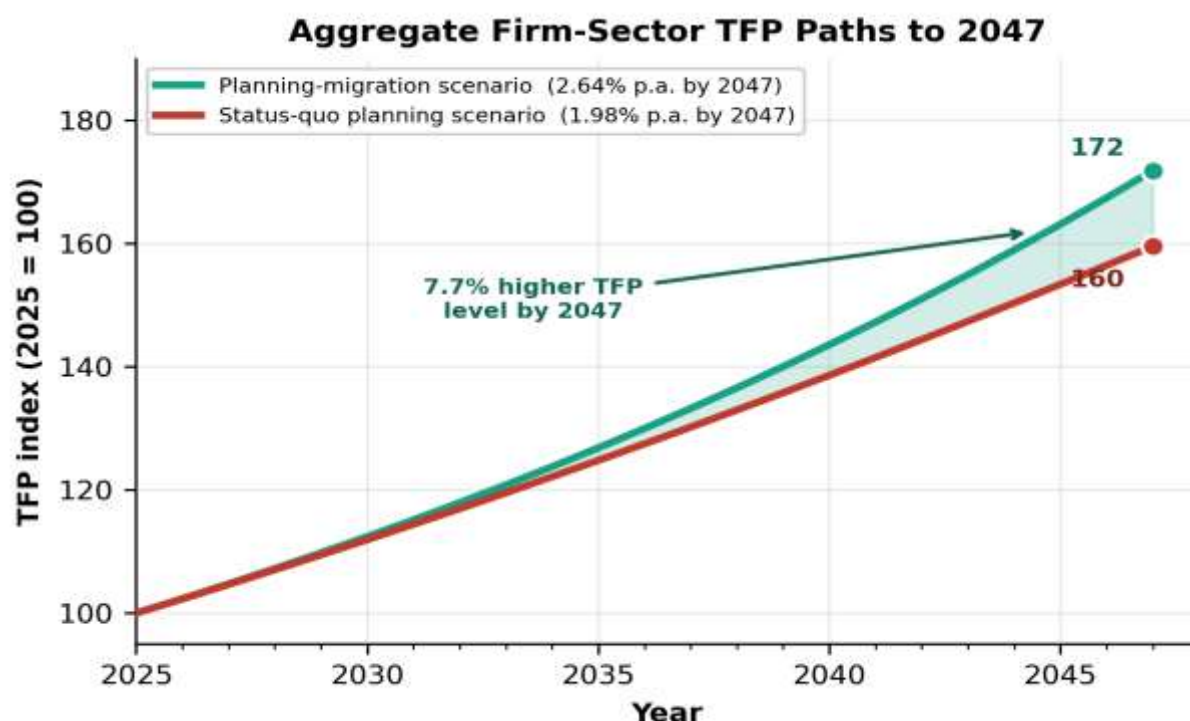


Fig. 7. Aggregate firm-sector TFP index paths to 2047 under alternative planning-migration scenarios.

Table 9. Summary of hypothesis tests

H	Statement	Evidence	Result
H1	Age-structure planning maturity is positively associated with firm TFP growth.	$\beta = 0.371$, $p < 0.01$; tier range 1.24% to 4.05%	Supported
H2	The relationship between mean workforce age and TFP growth is inverse-U shaped.	Age $\beta = 0.182$, $p < 0.05$; Age ² $\beta = -0.0042$, $p < 0.01$	Supported
H3	Planning maturity shifts the turning point upward and flattens the gradient.	Interaction $\beta = 0.0331$, $p < 0.01$; turning point 28.0 $\rightarrow$ 39.0 years; range 1.52 $\rightarrow$ 0.54 pp	Supported
H4	Age dispersion raises TFP growth in innovation-intensive firms only.	Interaction $\beta = 0.114$, $p < 0.01$; Q4 gap +1.57 pp	Supported
H5	Proportionate 2047 TFP loss is decreasing in planning maturity.	Loss 37.1% (P1) to 3.2% (P4); ratio 3.27 $\rightarrow$ 5.03	Supported

VII. DISCUSSION

The central finding of this study is that workforce ageing is not a productivity shock that firms receive; it is a productivity shock that firms partly author. The estimated turning point of the age–productivity relationship varies by eleven years across planning tiers, and the gradient beyond it varies almost threefold. Firms in the sample with the oldest workforces recorded the highest TFP growth, which would be paradoxical under any account in which age operates directly on productivity, and is unremarkable once planning is admitted as the mediating variable.

This reframes the demographic dividend debate in a useful way. The macro literature asks whether India will capture its dividend and answers in terms of education, employment generation and participation [4], [5], [10]. Those answers are correct and incomplete. A dividend is captured firm by firm, through the accumulated effect of decisions about pipeline depth,

knowledge documentation and retirement management. The state can enlarge the pool of available workers; only employers can determine what that pool produces.

The timing asymmetry deserves particular emphasis because it inverts the usual logic of investment urgency. The returns to age-structure planning are lowest today, when a young workforce and abundant external supply make replacement easy, and highest in the 2040s, when neither condition holds. But the capability cannot be acquired in the 2040s: successor pipelines take years to develop, tacit knowledge transfers only while its holders remain employed, and a firm that has not documented its critical processes cannot do so retrospectively once the people who understood them have retired. The investment must be made when its apparent value is least. This is a recognisable failure pattern, and it explains why a transition that is gradual in any single year can nonetheless produce discontinuous firm-level outcomes. It is worth noting that ageing may also induce compensating responses: Acemoglu and Restrepo find no negative cross-country association between ageing and growth, and argue that ageing economies adopt automation more rapidly precisely because scarce labour raises the return to it [18]. That mechanism operates on the capital side of the production function and does not substitute for the knowledge-continuity problem examined here, but it does caution against reading demographic ageing as unambiguously contractionary.

The dispersion results add a design consideration. Age diversity pays where work requires recombination and not where it does not [12], which means the correct age structure is not a single national or even sectoral target but a function of the task portfolio. A firm running routine operations and an innovation unit within the same organisation should not hold the same age distribution in both.

Finally, the results connect to the data-infrastructure and participation strands. Age-structure planning is a data-intensive capability, and the evidence on enterprise system integration indicates how large the gap between integrated and fragmented workforce records can be — improvements of the order of 75 per cent in operational efficiency and 80 per cent in data accuracy in the higher education systems studied [8]. Firms that cannot construct a forward age-and-capability projection are not choosing reactive planning; they are unable to choose anything else. And because human resource maturity is markedly lower among micro, small and medium enterprises [7], while effective labour supply is constrained more by participation than by age structure [9], [10], the aggregate transition will be determined as much by capability diffusion to smaller employers and by participation gains as by what large firms do.

VIII. IMPLICATIONS

A. Managerial Implications

Four operating implications follow. First, measure the age structure before managing it: a forward projection of headcount by age band, tenure and role criticality, at least ten years out, is the minimum basis for any planning claim, and firms without integrated workforce data should treat building that record as the prior task. Second, locate the firm's own turning point rather than assuming a general one — the estimates here range from 28 to 39 years and the difference is managerial, so a firm that knows its current mean workforce age and its planning maturity can determine whether it is approaching the peak or already descending. Third, calibrate age diversity to task type, pursuing heterogeneity in innovation-intensive units and coordination in routine ones. Fourth, treat tacit-knowledge transfer as time-bounded: it can only be done while the holder is employed, which makes it the one element of succession planning with a hard deadline.

The sequencing implication is uncomfortable but clear. The firms with the most to gain from age-structure planning are those whose workforces are currently youngest, because they have the longest runway and the lowest present cost — and they are precisely the firms for whom the case will look weakest on today's numbers.

B. Policy Implications

For policy, the results suggest that the demographic dividend agenda is incomplete if it addresses only the supply of workers. Diffusing planning capability to smaller employers, where human resource maturity is documented to lag [7], would raise the productivity yield of the same demographic input. Practical instruments include sectoral or cluster-level shared workforce-planning infrastructure, extension of workforce-composition reporting requirements to create the data on which planning depends, and incorporation of age-structure and succession metrics into existing enterprise development programmes. Comparative policy experience from economies further along the transition — covering phased retirement, age-inclusive recruitment and lifelong learning entitlements — offers a tested menu of instruments [22].

The participation evidence points the same way from a different direction. If the labour force dependency ratio is driven more strongly by female participation than by age structure [10], and if the constraints on women's economic participation are as documented — competing family obligations, social stereotyping and limited awareness of support schemes [9] — then participation policy and firm-level planning capability are complementary levers on the same outcome. Neither alone is sufficient: participation gains without absorptive capacity produce underemployment, and planning capability without participation gains operates on too small a base.

C. Theoretical Contribution

Theoretically, the study contributes a mediating term to the demographic dividend literature. The prevailing formulation treats the working-age share as an argument in an aggregate production function; the evidence here indicates that the mapping from age structure to productivity is itself firm-specific and managerially determined, with a turning point that varies by more than a decade across observationally similar firms. It also extends the firm-level age-productivity literature by identifying planning maturity as the variable that reconciles the individual-level finding of age-related decline with the organisational-level finding that ageing need not reduce productivity [11], [12]: both are true, and planning is what separates them. Finally, it offers a method for projecting firm-level demographic exposure that can be applied to any economy with published age-structure projections.

IX. LIMITATIONS AND FUTURE RESEARCH

Five limitations qualify these findings. First, planning maturity is not randomly assigned. Firms that invest in age-structure planning may differ in general management quality in ways the controls do not capture, so part of the estimated planning effect may reflect that broader competence. Instrumental-variable identification, perhaps using variation in ownership structure or regulatory succession requirements, would sharpen the estimate.

Second, the 2047 projection holds the estimated parameters fixed while shifting age. It therefore isolates the age-structure channel by construction and excludes technological change, capital deepening, changes in retirement age and any adaptation firms make in response to ageing itself. It should be read as a statement of what the age structure implies under current practice, not as a forecast of what will occur.

Third, the uniform 7.6-year age shift applied to all tiers is a simplification. Firms in different sectors and locations will age at different rates, and integrated planners may in fact manage their mean age actively rather than passively absorbing the national trend — which would make the projected divergence larger, not smaller.

Fourth, the sample requires firms able to supply age-banded workforce data, which biases it toward larger and better-instrumented organisations. Since those firms are more likely to occupy the higher planning tiers, the study probably understates the share of the wider economy in the reactive category and hence the aggregate exposure.

Fifth, the analysis is confined to formal-sector firms in five metropolitan clusters. India's informal sector, where the majority of employment sits, is neither observed nor represented here, and the planning constructs measured may not transfer to it in their present form.

Future research should pursue quasi-experimental identification of the planning effect; direct measurement of tacit-knowledge transfer and its productivity consequences; extension to micro, small and medium enterprises and to the informal sector; incorporation of retirement-age policy and phased-retirement design as explicit variables; and examination of the interaction between age-structure planning and the reskilling and redeployment practices that determine whether an ageing workforce can be recomposed rather than merely replaced, an area in which a century of training research offers design guidance that workforce-planning practice has not yet absorbed [20].

X. CONCLUSION

This study asked whether firm-level manpower and succession planning mediates the productivity consequences of India's demographic transition. Across 214 firms and 1,712 firm-years, the answer is that it does, and substantially. TFP growth rises from 1.24 per cent per annum in firms that fill vacancies as they arise to 4.05 per cent in firms that plan their age structure as an integrated system — a ratio of more than three to one within the same demographic environment.

The mechanism is not that planning keeps workforces young. It is that planning changes the shape of the relationship between age and productivity. The turning point of that relationship moves from 28.0 years under reactive practice to 39.0 years under integrated planning, and the spread of outcomes across age bands narrows from 1.52 to 0.54 percentage points. Firms in the sample with the oldest and most age-diverse workforces recorded the highest productivity growth, which is decisive against any reading in which ageing acts on productivity directly.

Applying India's projected 2047 age structure sharpens the point. Reactive firms lose 37.1 per cent of their TFP growth; integrated planners lose 3.2 per cent. The gap between them widens from a factor of 3.27 to a factor of 5.03. At the aggregate level, migrating firms toward structured and integrated planning would deliver a firm-sector TFP level 7.7 per cent higher in 2047 than the status quo — obtained purely by redistributing managerial practice that already exists in the economy.

The uncomfortable implication concerns timing. The demographic dividend is currently concealing the cost of poor age-structure planning, because a young workforce and abundant external supply make replacement cheap. That concealment will end in the 2040s, when the capability can no longer be built because the people who would have transferred the knowledge

will have gone. The window for acquiring the capability is open now, when its measured return is at its lowest. Firms and policymakers who wait for the case to become obvious will be acting at the point when action has ceased to be effective.

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