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Recruitment Tasks and Skill Requirements across Healthcare Supply-Chain Stages in China

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Abstract

How do recruitment tasks and skill requirements evolve across healthcare supply chains? We examine online job advertisements from China's pharmaceutical and medical-device manufacturing and distribution sectors in 2015–2022. A common text-classification framework distinguishes advertised tasks, skills and formal requirements, enabling annual comparisons across four supply-chain segments. A descriptive decomposition separates changes within segments from changes in their representation in the observed advertisements. Recruitment profiles differ across stages, and these differences evolve over time. In the later period, pharmaceutical manufacturers advertised sales and market-development tasks more often than distributors, while distributors more often requested scientific and medical knowledge and advertised quality, regulatory, clinical and technical-service work. Medical-device recruitment followed different trajectories, showing that stage differences depend on product category and year. The pooled increase in scientific-and-medical-knowledge requirements arose from changes within the four segments, with changes in segment composition slightly offsetting that increase. The study provides a consistent framework for comparing recruitment content across healthcare industries and identifies supply-chain position as an additional dimension of heterogeneity in advertised labour demand. These findings show how industry averages can conceal distinct recruitment trajectories across manufacturing and distribution.

Keywords: online job advertisements, task composition, skill requirements, pharmaceutical supply chain, medical devices, China

1 Introduction

Task-based research shows that the content of jobs and the skills employers request vary across occupations, firms and time (Autor 2013; Deming and Kahn 2018; Atalay et al. 2020). Recent management research on AI and work also relates changing job roles and interdisciplinary skill needs to organisational and institutional conditions (Doubková and Magdin 2026). Yet much less is known about whether a firm's position in a product supply chain is reflected in its advertised mix of work. Related healthcare-vacancy studies examine AI-related hiring in hospitals and digital and management capabilities in Chinese healthcare advertisements (Goldfarb et al. 2020; Chen

et al. 2025); they do not compare the combination of commercial, technical, regulatory and interpersonal requirements across manufacturing and distribution. This leaves a substantive question about the organization of labour demand: How have the task composition and skill requirements of recruitment evolved across different segments of China's pharmaceutical and medical-device supply chains?

China's pharmaceutical and medical-device supply chains make this comparison salient. Manufacturers concentrate on production, product development and quality control; distributors coordinate market access, transactions, logistics and customer relationships. These distinct functions need not produce equally distinct recruitment profiles. During the sample period, centralized volume-based procurement linked price competition to quality eligibility, purchasing-volume commitments and supply obligations. The first "4+7" drug pilot was announced in November 2018 and expanded nationally in 2019; national procurement of coronary stents followed in 2020 (Joint Procurement Office 2018; National Healthcare Security Administration 2019, 2020). This chronology makes commercial, scientific, service and regulatory vacancies worth examining together across stages and products, with 2018 serving as a reference year rather than a common treatment date.

We analyse 18,178 firm-matched, exactly deduplicated online job advertisements from 2015–2022 across four segments: pharmaceutical manufacturing and distribution and medical-device manufacturing and distribution. A common classification framework measures advertised tasks, skills and formal requirements consistently across the eight years, with ten screened characteristics used to describe recruitment profiles. We compare these profiles across products, supply-chain stages and years, and decompose changes in pooled recruitment shares into changes within segments and changes in the segments' shares of observed advertisements. This approach connects the evolution of industry-wide recruitment requirements to the different paths followed by its constituent segments.

The findings reveal distinct and evolving recruitment profiles across supply-chain stages. In 2019–2022, pharmaceutical manufacturers advertised sales and market-development tasks more often than distributors, while distributors more often requested scientific and medical knowledge and advertised quality, regulatory, clinical and technical-service work. These contrasts changed over time, and medical-device recruitment followed different paths, indicating that the relationship between supply-chain position and labour demand depends on both product category and year. In the pooled sample, scientific-and-medical-knowledge content increased by 8.6 percentage points between 2015–2017 and 2019–2022. Changes within the four segments account for this increase, while changes in their shares of observed advertisements slightly offset it. Together, these patterns show why industry averages can conceal differences in how recruitment evolves across manufacturing and distribution.

First, the paper extends the dimensions along which task-based labour demand is compared. Job-advertisement studies document differences across firms within occupations (Deming and Kahn 2018), changes within job titles over time (Atalay et al. 2020), and changes in posted skill requirements across local labour markets during recessions (Hershbein and Kahn 2018). By comparing medicines with devices and manufacturing with distribution, we show that product category and supply-chain position

provide an additional way to organize variation in advertised task bundles. The cross-functional contrasts also caution against inferring a firm's recruitment profile from its industry or stage label alone.

Second, the paper broadens the measurement of healthcare recruitment beyond a single occupation or skill domain. Existing vacancy studies have examined AI-related hiring in US hospitals and digital and management skills in Chinese healthcare advertisements (Goldfarb et al. 2020; Chen et al. 2025). Our 21-label codebook separates tasks, skills and formal requirements, and its ten provisionally screened measures are applied consistently across four supply-chain segments and eight calendar years. This yields a longitudinal comparison of manufacturing and distribution that complements those more targeted studies.

Third, the paper adds a labour-demand perspective to research on institutional change in China's pharmaceutical sector. Studies of centralized procurement have emphasized drug prices, affordability and firm investment (Yuan et al. 2021; Qiu et al. 2025). We instead document how recruitment profiles vary around the late-2018 institutional marker and show whether observed aggregate changes arise within the four segments or from their changing representation in the matched advertisement sample. This decomposition is descriptive: it clarifies what an industry-wide recruitment trend contains without attributing that trend to procurement or extending it to all vacancies.

2 Data and methods

2.1 Source data and sample construction

Recruitment records come from CnOpenData's Online Recruitment Website Information Data (CnOpenData n.d.). The project extract contains 51job advertisements linked to firms through a tax-survey crosswalk. We study postings dated 2015–2022 in pharmaceutical and medical-device manufacturing and distribution. The unit of observation is an advertisement; after applying the sample restriction and removing exact duplicates, the analysis contains 18,178 postings. The data-processing and classification workflow is illustrated in Figure 2. We interpret these records as evidence from an online recruitment channel, a distinction relevant to research documenting unequal participation in European online job search (Năstasă and Mocanu 2025).

Table 1 shows the distribution of the 18,178 advertisements across four segments and eight years. Pharmaceutical manufacturing accounts for 9,280 postings, just over half of the sample, followed by pharmaceutical distribution (4,387), device distribution (3,208) and device manufacturing (1,303). Annual totals range from 1,687 in 2020 to 2,720 in 2022. The unequal segment sizes make it important to examine segment-specific profiles alongside the pooled series.

2.2 Data process

We remove advertisements that repeat the same firm, publication date, title, description, tags and job function; postings on different dates remain distinct observations.

Table 1 Matched, deduplicated recruitment advertisements by sector and year, 2015–2022

Year	Pharmaceuticals		Medical devices		Total
	Mfg.	Dist.	Mfg.	Dist.	
2015	1,116	742	249	494	2,601
2016	1,122	601	191	404	2,318
2017	1,080	585	206	318	2,189
2018	1,105	627	211	400	2,343
2019	1,041	538	102	357	2,038
2020	959	350	83	295	1,687
2021	1,283	380	115	504	2,282
2022	1,574	564	146	436	2,720
Total	9,280	4,387	1,303	3,208	18,178

Notes: Mfg. denotes manufacturing and Dist. denotes distribution. Counts refer to exactly deduplicated online job advertisements matched to firms in the four segments; they are not a census of vacancies. Source: CnOpenData Online Recruitment Website Information Data (firm-matched project extract).

Classification uses the title, description, tags and function, while firm identity, sector and year are withheld from the model. A predefined 21-label codebook separates recruitment tasks, worker skills and formal requirements. An advertisement may carry multiple substantive labels when its text supports them.

To apply the same coding rule at scale, a local Qwen3:14b model labels a balanced sample of 600 advertisements (Yang et al. 2025). These teacher labels and a separate 100-advertisement development reference train label-specific classifiers based on character-level text features and logistic regression (Pedregosa et al. 2011). A separate Qwen review examined uncertain later-year predictions, but all trends reported here use the frozen supervised classifiers applied uniformly to every retained advertisement.

We assess the labels against a separate, sector-year-stratified holdout of 100 advertisements from 2018–2022. The screening rule was set at F1 ≥ 0.70 before reporting trends. Figure 1 shows that ten of 21 labels meet this threshold; sales and market development, scientific and medical knowledge, and communication and teamwork have F1 scores of 0.919, 0.875 and 0.878, respectively. Research-and-development tasks and digital/data/AI skills score zero and are excluded from the main trend claims.

2.3 Descriptive analysis

Our object of interest is the prevalence of each screened task, skill or requirement in observed recruitment advertisements, separately by product category, supply-chain stage and year. The analysis asks how manufacturing and distribution profiles differ, how they change from 2015 to 2022, and whether pooled changes reflect shifts within the four segments or shifts in their shares of the observed postings. Following research that uses vacancy text to measure advertised labour demand (Deming and Kahn 2018;

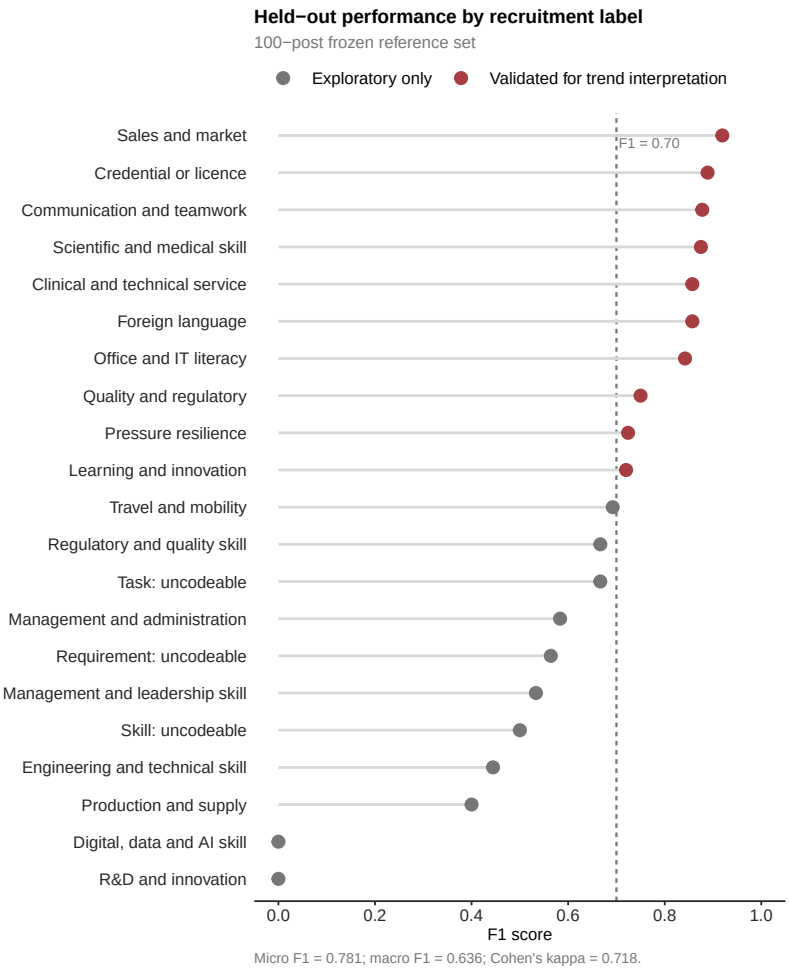


Fig. 1 Held-out F1 by recruitment label. The dashed line marks the pre-specified 0.70 threshold used to retain ten labels for the main descriptive analysis. F1 scores compare frozen predictions with a single Codex-assisted reference for 100 stratified 2018–2022 advertisements; they are not accuracy estimates against independently adjudicated human coding, particularly for the earlier years.

Atalay et al. 2020), we use descriptive proportions rather than treating postings as hires or the procurement chronology as a policy experiment.

For each label k, segment s and year t, we calculate the share of advertisements carrying that label:

$$\widehat{P}_{kst} = \frac{1}{N_{st}} \sum_{i \in (s,t)} Z_{ik}, \tag{1}$$

where $Z_{ik} = 1$ when the frozen classifier assigns label k to advertisement i, and N_{st} is the number of observed advertisements in the segment-year cell. We report these advertisement-weighted shares annually, pool the four segments for an overall series, and subtract distribution from manufacturing within each product category to display

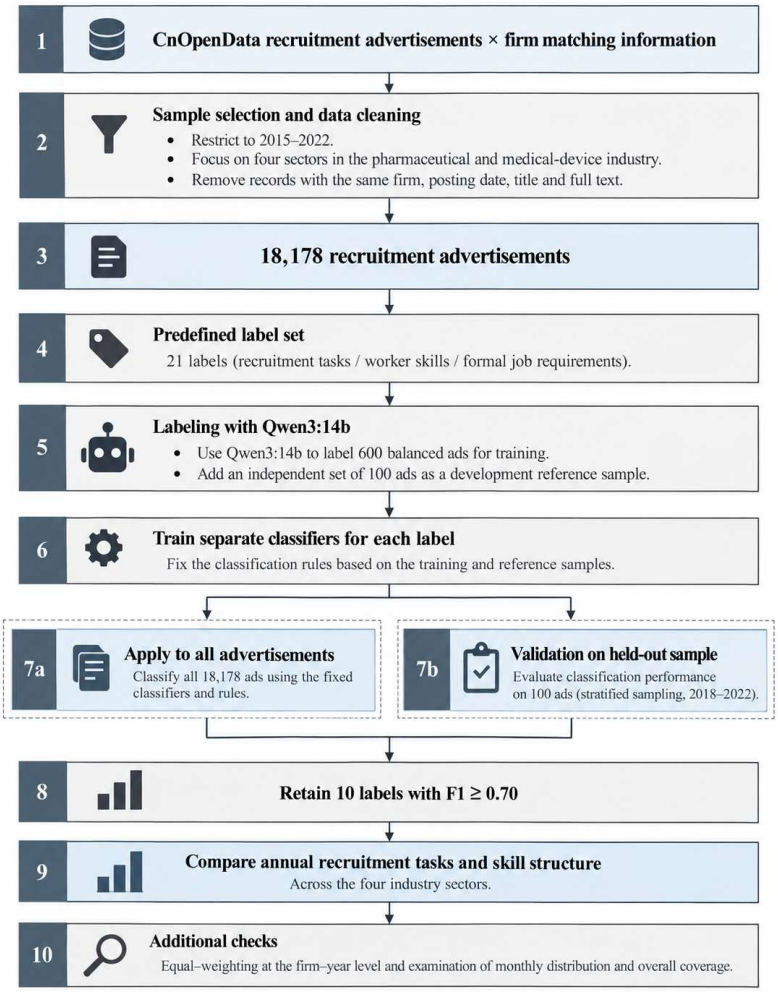


Fig. 2 Data-processing and classification workflow, from sample construction and label development to held-out validation and descriptive analysis.

stage gaps. Period summaries pool advertisements in 2015–2017 and 2019–2022, with 2018 shown separately; they do not weight years equally.

A pooled share can change because label prevalence changes within the four segments or because the segments account for different shares of the matched advertisements. To separate these sources descriptively, we use the symmetric rate–composition decomposition of Kitagawa (1955). Let A denote 2015–2017 and B denote 2019–2022, with $P_k^q = \sum_s w_s^q P_{ks}^q$, where w_s^q is segment s's share of advertisements in period q.

Then

$$P_k^B - P_k^A = \underbrace{\sum_s \bar{w}_s (P_{ks}^B - P_{ks}^A)}_{\text{within-segment change}} + \underbrace{\sum_s \bar{P}_{ks} (w_s^B - w_s^A)}_{\text{segment-composition change}} , \tag{2}$$

where each bar is the mean of its early- and later-period values. The identity is exact before rounding. We calculate it for all ten screened labels and show six in the main table. The within-segment term need not follow the same firms, while the composition term describes only the sector mix of this matched sample. We do not attach sampling confidence intervals to these non-probability platform data, as such intervals would also omit classification and source-selection uncertainty.

3 Results

Recruitment profiles differ across product categories and supply-chain stages, and these differences evolve rather than remaining fixed. We first compare the structure of advertised tasks and skills across the four segments, then trace their annual paths, and finally examine how segment-level changes contribute to pooled trends. All shares refer to observed advertisements, not hires or the full population of vacancies.

3.1 Structural changes in recruitment

Manufacturing and distribution do not divide neatly into technical and commercial recruitment. In 2019–2022, pharmaceutical manufacturers advertised sales and market-development tasks more often than pharmaceutical distributors (60.8 versus 44.3 percent), whereas distributors more often sought scientific and medical knowledge (60.0 versus 36.8 percent) and quality and regulatory tasks (31.0 versus 8.3 percent; Table 2). The manufacturing–distribution differences for medical devices were much smaller for sales and scientific knowledge. Product category therefore conditions the meaning of supply-chain stage: neither "manufacturer" nor "distributor" identifies a fixed bundle of advertised work.

The pharmaceutical contrast also changed between the early and later periods rather than reflecting a timeless division of functions. In 2015–2017, pharmaceutical distribution advertised more sales-and-market content than manufacturing (61.6 versus 55.3 percent) and less scientific-and-medical-knowledge content (29.9 versus 33.8 percent); both comparisons reversed in 2019–2022. One interpretation is that manufacturers can retain market-facing work while distributors combine transaction coordination with product knowledge, clinical support and regulatory compliance. The 2019 procurement expansion placed supply and quality obligations on winning manufacturers while allowing them to select delivery firms (National Healthcare Security Administration 2019), a policy context in which work at the two stages may remain interdependent. These advertisements reveal the allocation of advertised tasks, not why firms chose it. The cross-stage variation complements evidence that skill requirements can differ substantially even within occupational categories (Deming and Kahn 2018).

Table 2 Observed recruitment characteristics by sector and descriptive period, 2015–2022

Characteristic	2015–2017	2018	2019–2022
Device distribution			
Sales and market development	49.3	45.8	51.6
Clinical and technical service	40.4	45.5	47.4
Quality and regulatory tasks	11.4	15.8	12.7
Scientific and medical knowledge	39.1	45.2	46.4
Communication and teamwork	66.8	64.5	73.4
Credentials and licences	24.3	25.8	19.5
Device manufacturing			
Sales and market development	51.7	54.0	55.6
Clinical and technical service	37.2	48.3	37.4
Quality and regulatory tasks	5.3	2.4	5.4
Scientific and medical knowledge	50.2	56.4	42.8
Communication and teamwork	71.5	70.1	71.1
Credentials and licences	25.2	20.9	14.3
Pharmaceutical distribution			
Sales and market development	61.6	24.6	44.3
Clinical and technical service	26.1	52.0	41.7
Quality and regulatory tasks	13.6	38.9	31.0
Scientific and medical knowledge	29.9	66.8	60.0
Communication and teamwork	70.3	42.9	57.5
Credentials and licences	29.4	60.3	48.7
Pharmaceutical manufacturing			
Sales and market development	55.3	57.9	60.8
Clinical and technical service	33.9	35.3	31.4
Quality and regulatory tasks	13.1	9.9	8.3
Scientific and medical knowledge	33.8	31.5	36.8
Communication and teamwork	69.6	76.1	78.7
Credentials and licences	31.4	30.0	28.2

Notes: Cells are percentages of matched, exactly deduplicated advertisements in the indicated sector and period. The periods are descriptive; 2018 is shown separately because the first '4+7' pilot was announced late that year. The pooled 2019–2022 percentage weights advertisements, not years equally. All outcomes use one frozen supervised classifier. They describe observed advertisements, not all vacancies or hires; early-year label validity has not been independently human-validated.

3.2 Time pattern analysis

Recruitment requirements followed uneven, non-monotonic paths rather than a single break in 2018. Across the pooled sample, sales-and-market content fell from 58.7 percent of advertisements in 2015 to 46.6 percent in 2018, then reached 68.6 percent in 2022; clinical-and-technical service moved in the opposite direction around 2018 (Figure 3). An early-versus-later average captures the net shift but conceals these reversals, making annual comparisons essential to the descriptive question.

The timing and direction of adjustment also varied across segments. Pharmaceutical distribution shows a pronounced 2018 trough in sales-and-market content alongside a rise in scientific-and-medical-knowledge content, followed by a partial sales recovery; pharmaceutical manufacturing does not display the same combination (Figure 4, panel a). The manufacturing-minus-distribution gaps consequently change sign for both sales and scientific knowledge in pharmaceuticals, while the medical-device gaps follow different trajectories (Figure 4, panel b). The "4+7" drug pilot was announced only in November 2018 and expanded nationally in 2019, whereas national coronary-stent procurement followed in 2020 (Joint Procurement Office 2018; National Healthcare Security Administration 2019, 2020). This staggered chronology helps explain why one common time break is a poor description of all four segments, but the 2018 annual values cannot be read as responses to a late-year announcement. The evidence is of evolving advertised task content, not of a single policy-induced transition.

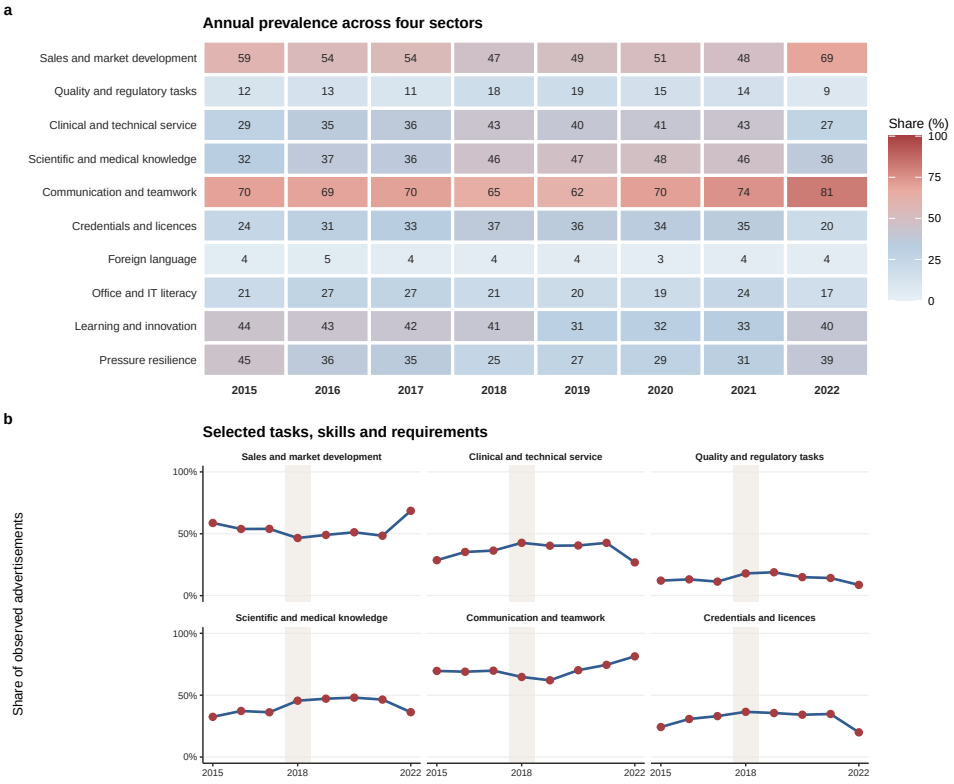


Fig. 3 Annual recruitment characteristics in the observed advertisements, 2015–2022. (a) Advertisement-weighted shares for all ten screened labels across the four segments; numbers are percentages rounded to whole points. (b) Annual trajectories for six selected labels. The shaded strip highlights 2018, when the first centralized procurement pilot was announced in November. The frozen classifier was applied to 18,178 deduplicated advertisements; early-year label validity has not been independently human-validated.

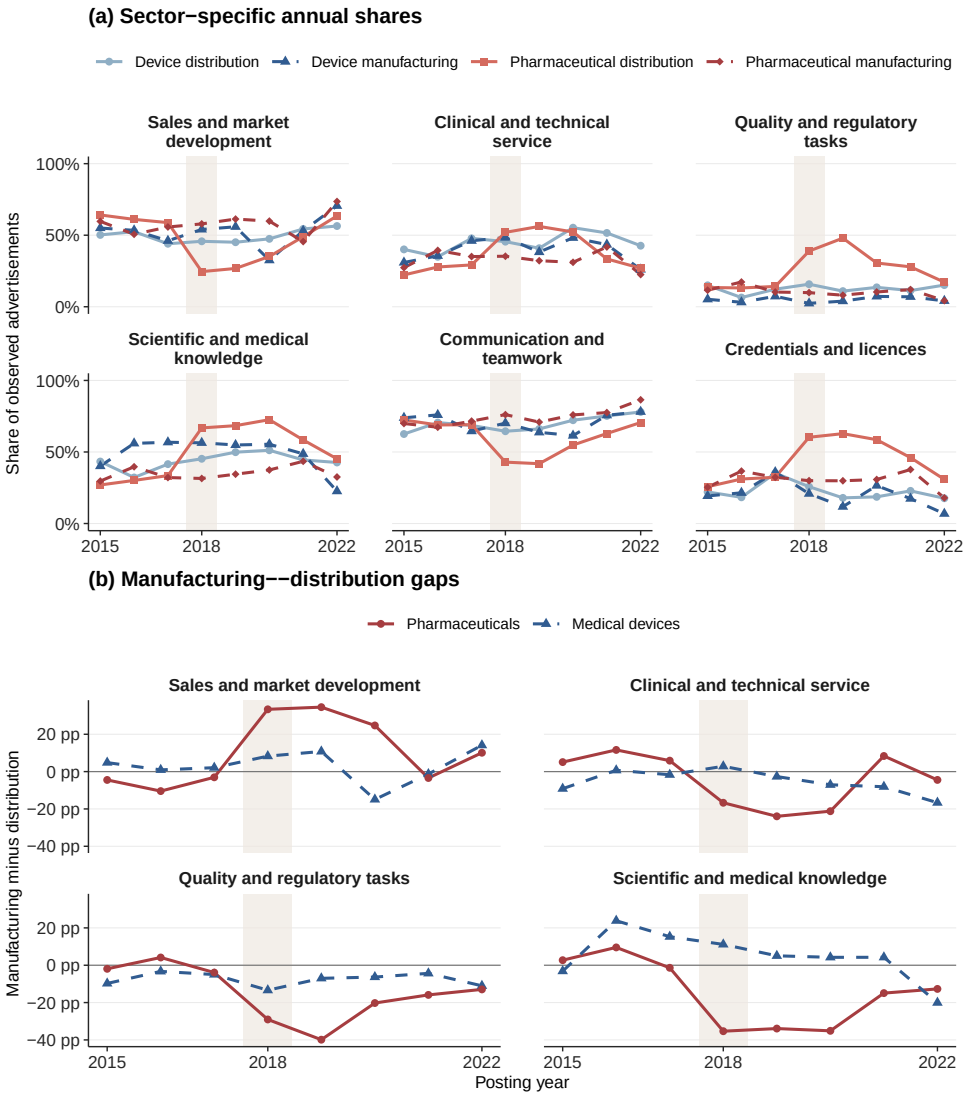


Fig. 4 Recruitment dynamics across product categories and supply-chain stages, 2015–2022. Panel (a) plots advertisement-weighted shares for six screened characteristics in four segments. Panel (b) plots manufacturing-minus-distribution gaps for four characteristics within pharmaceuticals and medical devices; positive values indicate greater prevalence in manufacturing. The shaded strip marks 2018. All values use the frozen classifier and observed advertisements.

3.3 Within-segment changes and aggregate recruitment trends

Changes within the four product-by-stage segments, rather than changes in their shares of matched advertisements, account for the observed pooled rise in scientific-and-medical-knowledge content. The pooled share increased by 8.6 percentage points from 2015–2017 to 2019–2022; the symmetric decomposition assigns +9.5 points to within-segment changes and -0.9 points to changes in the observed segment mix (Equation 2; Table 3). Clinical-and-technical service and quality-and-regulatory tasks show the same qualitative pattern. Thus the broad sector mix of the matched advertisements does not, by itself, explain the growth in these advertised requirements.

An almost unchanged pooled share can also conceal considerable changes in its component segments. Sales-and-market content was 55.7 percent in 2015–2017 and 55.4 percent in 2019–2022 overall, despite the reversal of the pharmaceutical manufacturing–distribution gap and the non-monotonic annual path. Aggregate stability should therefore not be mistaken for stability in each part of the supply chain. This accounting perspective parallels work showing that aggregate changes in task content can arise within established occupational categories (Atalay et al. 2020), while extending the comparison to product-by-stage segments. Here "within segment" does not mean within the same firms: firms, occupations and advertisements may differ across periods.

Table 3 Accounting for changes in observed recruitment profiles across four supply-chain segments

Characteristic	2015–2017	2019–2022	Change	Within	Composition
Sales and market development	55.7	55.4	-0.3	-0.7	+0.4
Clinical and technical service	33.2	36.8	+3.6	+3.7	-0.1
Quality and regulatory tasks	12.2	13.7	+1.5	+2.0	-0.5
Scientific and medical knowledge	35.2	43.7	+8.6	+9.5	-0.9
Communication and teamwork	69.5	72.9	+3.4	+2.7	+0.7
Credentials and licences	29.1	30.2	+1.1	+1.4	-0.3

Notes: Early and later columns are percentages of observed advertisements; change, within-segment change and segment-composition change are percentage points. The four segments are pharmaceutical and device manufacturing and distribution. Each pooled period weights advertisements, not years equally; 2018 is shown separately elsewhere. The symmetric identity uses the mean of early and later segment weights for within changes and the mean of early and later segment prevalences for composition changes. The two components add to the change before rounding. Composition describes only the sector mix of matched advertisements, not all vacancies.

4 Discussion

The findings suggest that supply-chain position helps organize differences in advertised labour demand, while the boundaries between commercial and technical work extend across manufacturing and distribution. The later-period pharmaceutical profiles illustrate this overlap: manufacturers more often advertised sales and market-development tasks, whereas distributors more often requested scientific knowledge and advertised

regulatory and technical-service work. One interpretation is that manufacturing firms retain market-facing activities while downstream firms combine transaction coordination with product expertise and service provision. A recent review links customer knowledge, supply-chain knowledge and intellectual capital to business model innovation (Liu et al. 2026a), providing a conceptual basis for examining expertise alongside commercial activity. Our recruitment comparison complements that perspective by locating advertised knowledge requirements across supply-chain stages. It also extends studies documenting skill-demand differences across firms within occupations (Deming and Kahn 2018): the economic functions associated with supply-chain stages provide another useful context for understanding the task bundles employers advertise. The different contrasts observed for medical devices further suggest that stage should be considered together with product category.

The changing direction of these contrasts also matters. A comparison at a single point in time could make a temporary recruitment profile appear to be a permanent feature of manufacturing or distribution. The annual series instead show that commercial and knowledge-related requirements followed different paths across the four segments. Centralized procurement provides a relevant institutional setting for interpreting this coexistence of requirements. The 2019 expansion combined purchasing-volume commitments with quality and supply obligations and allowed manufacturers to select delivery firms (National Healthcare Security Administration 2019). These arrangements connect production, delivery and market access, making coordination across stages a plausible context for the continued presence of commercial work alongside scientific, regulatory and service requirements. The later chronology of coronary-stent procurement adds to the reasons for examining pharmaceuticals and devices separately (National Healthcare Security Administration 2020). This interpretation concerns the functions highlighted by the institutional setting; identifying how individual firms reorganized those functions would require additional evidence.

The decomposition clarifies what the aggregate recruitment trend contains. The increase in scientific-and-medical-knowledge requirements arose within the four broad segments, while their changing representation in the observed advertisements slightly offset the increase. It therefore reflects more than a shift toward segments with higher initial knowledge requirements. Conversely, the nearly stable pooled sales share conceals changing manufacturing–distribution contrasts and distinct annual trajectories. This parallels the insight from Atalay et al. (2020) that changes within established job categories can be central to the evolution of aggregate task content. Our comparison applies that accounting perspective to supply-chain segments. Changes within a segment can still involve different firms and occupations, so the result describes where the observed change is located rather than establishing adjustment within the same employers.

The study contributes a common measurement framework for examining these differences over time. Healthcare-vacancy research on AI hiring in hospitals and digital and management capabilities in Chinese recruitment has illuminated particular dimensions of skill demand (Goldfarb et al. 2020; Chen et al. 2025). Measuring commercial, scientific, regulatory, service and interpersonal content together shows how

these requirements coexist across manufacturing and distribution. For workforce planning, the implication is to consider combinations of knowledge and tasks within each product-and-stage setting: training directed only at technical capabilities in manufacturing or sales capabilities in distribution may overlook the broader recruitment profiles observed here. Supply-chain position thus complements occupation and firm characteristics in describing labour demand (Autor 2013; Deming and Kahn 2018). The evidence concerns advertised requirements in the matched sample; its practical value lies in revealing distinctions that an industry-wide recruitment average would conceal.

A further research question concerns how external monitoring environments relate to recruitment for quality and regulatory work. Liu et al. (2026b) document an association between greater media geographic proximity and lower corporate misconduct in China, with information-dissemination speed more closely related to this pattern than information quality. Linking recruitment records to local media exposure would allow future research to examine whether advertised compliance and knowledge requirements vary with external monitoring conditions.

Statements and Declarations

Ethics approval and consent to participate

The study analyses job advertisements and firm identifiers. No human-subject interaction occurred. The applicable institutional ethics determination is pending confirmation by the authors.

Consent for publication

Not applicable.

Data availability

The derived files, prompts, codebook, cleaning audit, model outputs and analysis scripts are preserved in the project replication archive. Access to the underlying CnOpenData recruitment records and matched tax-survey data is subject to provider and project-specific terms; redistribution of those files is subject to provider and project-specific permissions.

Use of artificial intelligence

Local Qwen outputs were used to construct teacher labels and review uncertain cases in the text-classification pipeline. Codex-assisted coding supplied the single development and holdout reference used to assess that pipeline. Two additional Codex AI agents separately coded a 60-advertisement blind spot-check; this AI-only review is not independent human validation. AI assistance also contributed to analysis code and manuscript drafting. The authors remain responsible for the final analyses and text.

Competing interests

The authors declare that they have no competing interests.

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