Resource allocation and growth strategies in a multi-plant firm:

Kanegafuchi Spinners in the early 20^{th} century

Shotaro Yamaguchi
University of Maryland, Robert H. Smith School of Business
shotaro@umd.edu

Serguey Braguinsky
University of Maryland, Robert H. Smith School of Business, NBER, and Osaka University ISER
sbrag@umd.edu

Tetsuji Okazaki
University of Tokyo, Faculty of Economics
okazaki@e.u-tokyo.ac.jp

Takenobu Yuki
Tohoku University, Faculty of Economics
takenobu.yuki.c1@tohoku.ac.jp

Abstract

Using detailed plant- and individual-level data from a major Japanese cotton spinning company in the early 20^{th} century, we examine the within-firm allocation of skilled human capital in conjunction with investment in physical capital, accompanying the firm's evolving strategic priorities. We show that the firm leveraged unit-level two-way complementarity between managerial talent and strategically important plants when the task was achieving large-scale output and positioning for a competitive cost advantage. The task of conducting product differentiation, however, ushered in "three-way complementarity," where educated engineering human capital and capable managers needed to be bundled with specialized physical capital. A deeper dive into the "nano-economics" of resource allocation reveals that educated engineers experiencing product differentiation in pioneering plants were reallocated to other plants also pursuing product differentiation.

Keywords: resource allocation, firm strategy, multi-plant firms, managerial human capital, engineering human capital

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1. Introduction

How do firms allocate human capital resources, especially skilled human capital, across establishments to accomplish the desired positioning of the firm, and how do firms create such resource alignment? Internal allocation and reallocation of skilled human capital is a key issue in strategic management because its supply is generally limited and cannot be used for multiple uses at the same time due to its non-scale free nature (Levinthal and Wu, 2010; Wu, 2013). However, few studies have examined how (multiple) competitive and growth strategies translate into strategic (re-)allocation of skilled human capital within firms (Maritan & Lee, 2017). Partly this is due to a lack of suitable data, making it difficult to observe (i) individual workers' internal transfers across establishments and (ii) the heterogeneity in those workers in terms of educational backgrounds, skills and expertise, and prior work experience.

In this paper, we take a deep dive into within-firm human capital (re-)allocation in conjunction with investment in physical capital, as it was linked to the firm's evolving strategic priorities by examining about two decades of history of Kanegafuchi Spinners (hereafter, Kanebo, after its Japanese acronym) at the beginning of the 20th century. Kanebo was one of the early private entrants into Japan's cotton spinning industry and became one of the "center of gravity" firms by the late-1900s (Agarwal et al., 2020).[1] Over the period covered by our data, Kanebo had grown from a single-plant, standard-product firm to a 16-establishment company with a highly diversified product portfolio, while shifting its strategic focus from cost advantage based on simple, basic yarns to product differentiation involving high-quality, processed yarns and fabrics.[2] Importantly, the firm implemented product differentiation only in select plants and allocated different kinds of human capital accordingly. We leverage rich and unique archival plant-level data to answer the following research questions in

[1] The phenomenal growth of the Japanese cotton spinning industry from the late 19th to the early 20th century has attracted much attention in economics and management literature. See, for instance, Saxonhouse, 1974; Braguinsky et al., 2015; Braguinsky & Hounshell, 2016; Agarwal et al., 2020; Braguinsky et al., 2021.

[2] Kanebo also diversified into silk spinning, but that part is a separate industry and is outside the scope of our analysis.

this paper. How does a firm strategically build and (re-)allocate the stock of human capital at different levels and roles across establishments? How do plant-level competitive and growth strategies map into such human capital allocations, and how complementary are human capital and different kinds of physical capital? What are the dynamics of human capital allocation and reallocation as a firm initiates product differentiation in a growing number of plants?

The single-firm case of Kanebo is ideal for addressing these questions for the following reasons. First, our motivation lies in a firm's endogenous resource allocation decisions and how such resource allocation evolves in the process of growth from a small startup to a leading firm in a major industry. In our context, we can look at Kanebo's different unit-level strategies (e.g., cost advantage v. product differentiation) implemented in different plants at different points in time and accompanying resource allocation strategies within a single firm so that it controls for unobserved initial conditions along with firm- and industry-specific characteristics. Second, we believe that unpacking endogenous resource allocation processes requires embracing a firm's underlying decision-making as well as various complementary activities surrounding those decisions, including resource acquisition from external capital and labor markets, product market positioning, learning and procurement of production technologies, human capital investment, and so on (Maritan and Lee, 2017). Such in-depth analysis is often challenging in quantitative studies based on a large number of firms.

Third, as described in detail in Section 3 and the online appendix, Kanebo's archival records and complementary external sources are exceptionally rich and help us answer the questions above. The data include plant-level appointments of plant managers, engineers at various levels, and skilled blue-collar workers trained at its internal vocational school, complemented by university and college alumni registries and a comprehensive cotton-spinning industry database for their educational backgrounds and industry careers. We also have detailed plant-level information on the types of products, inputs and outputs, scale and type of production machines, machine orders, worker turnover, and plant-level balance sheets and income statements. This unique level of detail allows us to examine how high-level human capital (managers, engineers, and skilled workers) were (re-)allocated across plants that had different capital capacity, had recently been acquired or newly established, and targeted different types of differentiated products (low-end yarns, high-end yarns, fabrics).

Our in-depth single-firm study provides several key insights related to internal human capital allocation. First, we find unit-level two-way complementarity between physical capital and managerial capital in the firm's positioning for a competitive cost advantage. The best managerial resources needed to be matched with the largest physical capital to maximize cost efficiency gains, considered as the within-firm implementation of positive assortative matching between ability and physical capital (Becker, 1973; Agarwal & Ohyama, 2013). Second, high-quality managerial talent was also allocated to newly acquired plants to resolve the integration challenge and increase productivity (Capron, 1999; Helfat and Raubitschek, 2000; Mitchell and Shaver, 2003; Zollo and Singh, 2004; Capron and Mitchell, 2009; 2012). Third, product differentiation required matching relevant physical capital (machines designed to produce differentiated products) with managerial and engineering human capital bundled together. That is, we find a three-way complementarity between managers, engineers, and physical capital aimed at differentiated products (Rubens, 2022). Finally, we find cross-plant spillovers in product differentiation that took place through the reallocation of managers and engineers from pioneering plants where they experienced the production of differentiated products to other plants that were newly tasked with product differentiation.

Our paper contributes to the literature on intra-firm resource allocation and reallocation by highlighting the unit-level complementarity between physical capital (machines and production technologies) and different kinds of human capital (managers, engineers, and skilled workers). Our in-depth examination reveals that even within the same firm, resource allocation decisions to meet different growth strategies exhibit distinct complementarities: two-way complementarity between managerial talent and large plants/newly acquired plants for cost advantage and three-way complementarity between managers, engineers, and high-end machines for product differentiation.

2. Theoretical overview

We build off the theoretical model in Agarwal and Ohyama (2013), which considered the allocation of talent across sectors (industry v. academia) in relation to various complementarities and apply the insights from that model to the within-firm human capital allocation problem. In doing so, we derive four theoretical propositions regarding the unit-level complementarity between different kinds of human capital and physical capital that guide our empirical analysis.

We first consider how the allocation of managerial human capital relates to unit-level physical capital. If a product is homogeneous and production technologies are common, the key task is to reduce marginal costs by improving unit-level production efficiency. Unit-level human capital, in particular, managers of establishments, plays an important role in determining the production efficiency of the unit (Ployhart and Moliterno, 2011; Crocker and Eckardt, 2013). Given that managers vary in their quality and only one manager can be assigned to each plant, the optimal allocation involves positive assortative matching between plant capital capacity and managerial talent (Becker, 1973; Agarwal & Ohyama, 2013).

To elaborate a little more on managers' assignments to heterogenous plants, consider a firm with *n* plants, whose capital capacity is represented by an *n*-tuple $\langle \gamma_1, \gamma_2, \ldots \gamma_n \rangle$, where γ_k denotes plant *k*'s stock of physical capital. For now, we assume that the plants are similar in all other respects except for size. Each plant requires one manager to manage it. Let the *n*-tuple of available heterogeneous managers be denoted by $\langle m_1, m_2, \ldots m_n \rangle$, where m_i denotes manager *i*'s managerial ability (human capital).[3] Let the output of plant *k* managed by manager *i* be given by $y_{ik} = m_i f(\gamma_k)$,

[3] We implicitly assume that high-ability managerial human capital is scarce and cannot be easily purchased in the market (e.g., Lucas, 1978). We present the evidence for this from our data below, in Sections 4 and 5.

where $f(\cdot)$ is a continuous, twice differentiable, and concave production function satisfying all the standard conditions. This setup implies that to maximize total output (i.e., $\sum_{k=1}^{n} y_{ik}$), the manager with the highest ability should be assigned to the largest plant (spreading his ability over the largest capacity), the second-best manager to the second-largest plant, and so on (Becker, 1973, p. 323; Agarwal and Ohyama, 2013, Lemma 1). That is, we have:

Proposition 1: Plants with larger capital capacity are more likely to have high-quality plant managers (two-way complementarity between managerial talent and physical capital).

However, firms may not fully enjoy economies of scale if production processes are poorly operated. This is particularly likely to be the case for newly added plants, such as through acquisitions. Scholars have pointed out the cost and difficulty of integrating separately held establishments due to gaps in routines and cultures (Capron, 1999; Helfat and Raubitschek, 2000; Mitchell and Shaver, 2003; Zollo and Singh, 2004; Capron and Mitchell, 2009; 2012). Such difficulties can, however, be mitigated by assigning a capable manager, especially a manager with prior experience managing existing units, to the newly added unit (Capron et al., 1998). That is, transplanting best practices, which largely involve tacit knowledge, would require a direct transfer of individuals who possess the relevant skills and knowledge (Argote & Ingram, 2000; Choudhury, 2020; Stadler et al., 2021). Using simple notation similar to above, denote the temporary cost of integrating a new unit into the firm by some fixed amount of output loss δ, and assume that a manager can limit this loss proportionate to his ability. Then, for some time period during which the plant has not yet been integrated into the firm, the total output of the newly acquired plant can be expressed as $y_{ia} = m_i f(\gamma_a) - (\delta / m_i)$, where subscript *a* denotes a newly added plant (unit). We have:

Proposition 2: For some period of time after they are added to the firm, newly added plants are more likely to have high-quality plant managers than other existing plants, even controlling for capital capacity.

Human capital allocation decisions are likely to become more complicated as the firm initiates product differentiation based on new technologies. Specifically, when establishments introduce new technologies, the allocation of human capital with specialized expertise (such as engineering) becomes particularly important (Stadler et al., 2021). Rubens (2022) uses historical data from Pennsylvania mines to demonstrate that there might indeed be strong complementarity between launching a new technology and having engineers educated in this technology to oversee its implementation. Thus, in pursuing product differentiation requiring advanced technological knowledge, high-ability engineers need to be matched with physical capital aimed for such differentiated products. At the same time, high-quality managerial talent is still required, as penetration into new product spaces requires not just technological prowess but also different managerial practices and updates of production routines. We can express the production function for high-end, differentiated products as $y_{ijk} = m_i e_j f(\gamma_{kH})$, where e_j is engineering human capital of engineer *j*, and γ_{kH} is the stock of physical capital designed specially to produce high-end, differentiated products. This kind of a production function gives rise to a three-way complementarity between managers, engineers, and physical capital in product differentiation (see Agarwal & Ohyama, 2013, Proposition 1, which establishes complementarity between physical capital and basic and applied scientists in industry):

Proposition 3: Plants conducting product differentiation are more likely to have high-quality plant managers and engineers bundled together than those that are not (three-way complementarity between managers, engineers, and physical capital).

Finally, introducing new technologies and expanding the number of units that adopt those new technologies often requires reallocating the limited and non-scale free stock of human capital with suitable skills and knowledge to units tasked with introducing such new technologies, as those individuals serve as the conduits of knowledge transfer (Argote & Ingram, 2000; Choudhury, 2020; Stadler et al., 2021). Thus, in the dynamic process of a firm's repositioning, we expect skilled managers and engineers with prior experience in working on product differentiation in pioneering plants to be reallocated to newly added plants also conducting product differentiation:

Proposition 4: High-quality managers and engineers who worked in pioneering plants conducting product differentiation are more likely to be reallocated to other plants initiating product differentiation than those who did not.

We build off these propositions in our empirical examination. Below, in Section 4, we use quantitative methods to show *what* Kanebo did to achieve the aforementioned two-way and three-way complementarities. In Section 5, we then take a deep dive into Kanebo's history and use detailed individual-level "nano-economic" data to show *how* the human capital stock necessary to implement those complementarities was procured and then (re-)allocated. Before that, in the next section, we briefly describe the contextual background and data we utilize (more details in Appendix B).

3. Historical context, data, and analytical approach

3.1 Background: The Japanese cotton-spinning industry in the late 19th-early 20th century

The mechanized cotton-spinning industry in Japan started from scratch in the 1870s but quickly achieved remarkable growth and became a leading export industry by the turn of the 20th century, contributing to Japan's rapid ascension to become the first industrialized country in Asia (Saxonhouse, 1974, Braguinsky and Hounshell, 2016). This growth was primarily achieved by a handful of firms that focused on value creation as opposed to value appropriation (Agarwal et al., 2020). Those firms grew into "centers of gravity" in the industry by attaining high levels of production and managerial efficiency, acquiring and restructuring the production systems of other, less efficient firms, and initiating product upgrades and diversification (Braguinsky et al., 2015; Agarwal et al., 2020; Braguinsky et al., 2021).

Kanebo was one of the most successful firms that implemented those growth strategies. When its first mechanized cotton spinning plant based in Tokyo started operating in 1889, it had the capacity of over 30,000 spindles, making it the largest startup in the nascent industry at the time of launch. A few years later, Kanebo received a capital injection from the Mitsui group (one of the largest business groups in Japan), which installed a new top management team and dispatched a university-educated professional manager, Sanji Muto (1867-1934) from Mitsui bank, to manage the newly established plant in Hyogo (see Figure 1 for the geography of Kanebo plants). In 1900, Muto was given control over all plant operations of the company and became the *de facto* general manager even though he was formally appointed as its CEO only in 1908. As such, he was the key figure behind Kanebo's strategic expansion, which went through several phases during the period covered by our data.

Around 1914, Kanebo was the largest firm in the industry in terms of output scale, although two mega-mergers between its competitors in 1914 and 1918 created two even larger firms. Kanebo's firm-level growth strategy enabled by its stable, shared leadership is detailed in Agarwal et al. (2020). In this paper, we leverage Kanebo's detailed plant-level data to examine how its strategy translated into human capital investment and internal (re-)allocation across plants.

3.2 Data

Kanebo left rich archival records, including those related to human capital it employed with detailed allocation to plants as well as positions held. Those records give us information about when, where, and how managers and senior engineers were employed in the company. We matched these data with the university and college alumni data, utilizing our own-constructed panel data on the universe of all university and technical college graduates in Japan until the 1920 graduation cohorts that include their job histories (see Appendix B for the details). This matching process allowed us to add information about the careers of those individuals before and after they were employed by Kanebo, as well as made it possible to identify all the educated engineers (university graduates and technical college graduates) whom Kanebo employed in non-managerial positions. The result is an individual-level panel data on plant managers (511 semi-annual observations on 35 unique individuals) and engineers in all positions (2,314 semi-annual observations on 176 unique individuals) with information about their educational backgrounds, prior job experience, future careers, and promotion status.

Apart from the plant managers' and engineers' data, the records contain plant-level data on the number of workers employed in each plant, their turnover, as well as plant-level assignments of blue-collar workers trained at Kanebo's own internal vocational school that the company launched in 1906. We also have access to plant-level financial data, such as semi-annual balance sheets and income statements, and input and output data for different types of products (see Appendix B). Furthermore, we utilize Kanebo's plant-level machine orders data from Lancashire archives (Braguinsky et al., 2021 and 2021a) which contain information on machines' technical characteristics, allowing us to observe the timing of each plant's capital expansion (i.e., machine purchases) aimed at producing different kinds of products. In particular, we are able to distinguish between machines designed to produce simple, low counts of cotton yarn ("low-end" machines) and machines designed to produce higher counts' yarn and further process such as doubling, gassing, and weaving ("high-end" and/or specialized machines), which required more advanced skills.[4] As high-end and specialized machines embodied novel and more challenging technologies, they required educated engineers to complement them (Rubens, 2022). We utilize the information about machine orders when examining human capital (re-)allocation following plant-level expansion events. Combining all the plant-level information, we construct an unbalanced plant-level panel dataset (465 semi-annual observations on 16 plants). Table 1 lists the plants in our sample, together with their origins (built v. acquired) in column (4), original capital capacity and its expansion (columns (5)-(7)), and whether and when they were assigned to implement the product differentiation strategy (columns (8) and (9)).

[Table 1 around here]

[4] The yarn count expresses the thickness of the yarn, and its number indicates the length of yarndence relative to the weight. The higher the count, the more yards are contained in the pound of yarn, so higher-count yarn is thinner (finer) than lower-count yarn and sells at a higher price per pound. Producing higher-count (finer) yarn requires better quality raw cotton as well as different machines and superior technology than producing lower-count (coarser) yarn. High-count yarn is often also improved further by more processing, known as doubling and gassing, which were quite challenging for the fledgling Japanese cotton spinning mills to master at that time. See Braguinsky et al. (2021) for more details.

Finally, we also utilize rich qualitative information to bolster our historical analysis, including regular notice letters, disseminated from Kanebo's general manager—Sanji Muto—to plant managers (*Shihainin Kaisho,* 1902-1918), Muto's biography, his 1901 essay (Muto, 1901) as well as Kanebo's company history (Kanebo, 1988). We describe the details of each data source in Appendix B.

3.3 Analytical approach

We adopt a mixed-method approach combining quantitative analysis with a deep dive into business history data (Braguinsky & Hounshell, 2016; Agarwal et al., 2020; Wormald et al., 2021). As described in the previous section, the uniqueness of our study rests on the comprehensive plant-level database of resources, costs, and outputs obtained from Kanebo's financial reports, and the individual-level panel data on plant assignment of managers and engineers constructed by various sources. The nature of the database is appropriate for our goal to delineate the process of human capital allocation across plants and examine the linkage between heterogeneous skill- and experience-levels of those human capital and their allocation. Our analytical approach also aligns with history-informed research and abductive methods (Ingram et al., 2012; Kahl et al., 2012; Murmann, 2012; Argyres et al., 2020; Pillai et al., 2020), whose primary goal is to infer the best explanations for phenomena observed in particular historical contexts.

4. Growth strategies and resource allocation: an overview and quantitative analyses

In this section, we first present an overview of the main insights supported by quantitative evidence regarding key differences in resource allocation as driven by the two basic competitive and growth strategies—cost leadership based on standard, homogenous products (lower-count, coarser yarns) coupled with acquisition-based production scaling, and internally developed product differentiation based on high-end products (higher-count, finer yarns) and fabrics. Our aim here is to present the basic evidence, linking it to some well-known theoretical constructions while at the same time striving to simplify the logic of a deep dive into Kanebo's business history in the next section.

4.1 Cost leadership and two-way complementarity of managers and physical capital

We begin with the strategy of achieving a competitive cost advantage. In a multi-plant firm context, this requires allocating top managerial talent to the most important plants. The plant's importance can be driven simply by its size (Proposition 1 above) or the need to integrate a new or newly acquired plant into the firm (Proposition 2 above).

Strictly speaking, testing Proposition 1 requires ordering managers according to their ability and showing that the largest plant gets assigned the best manager, and so on. We do not have a perfect measure of managerial ability; so instead, we construct four different proxies for several aspects of such ability and examine how the relative size of the plant at any given point in time on average affects the probability of its manager possessing higher ability as captured by each of those proxies. The four proxies are: (i) a dummy equal to one if the manager had higher education and zero otherwise; (ii) a dummy equal to one if the manager had prior experience managing a different plant at Kanebo and zero otherwise; (iii) a dummy equal to one if the manager had both higher education and prior experience managing a different plant at Kanebo and zero otherwise; and (iv) a dummy equal to one if the manager was subsequently promoted to the Kanebo board of executives and zero otherwise.[5] The idea behind the fourth proxy is that plant managers who later became executives would already have possessed higher ability than other managers at the time they were appointed.[6]

The estimation results are presented in Table 2. The dependent variables are the four dummies above, while the independent variable is the (logged) plant capital capacity (the number of spindles

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[5] Since some plant managers were appointed midway through the semiannual period, which is the basic unit of our observations, we use weighted dummies in case the change happened during the period. For example, if an educated manager replaced a manager without formal education in May 1902, the "educated plant manager" variable would be set to 1/3 for the first half of 1902 because the educated manager oversaw the plant for two months out of six.

[6] Experience managing a large plant could have contributed to developing the capability that later led to promotion or could have simply raised the visibility of the manager. Though such reverse causality is a possibility, note that it is enough for our purposes that future promotion is at least partially correlated with inherent managerial ability, which seems to be a plausible assumption.

installed) in a given plant in a given period, controlling for half-year and plant location fixed effects.[7] We employ the linear probability model, but probit and logit specifications yield similar results.

[Table 2 around here]

The estimation results in Table 2 show that higher plant capacity is positively associated with the probability of the manager possessing each of the four characteristics above.[8] The magnitudes are economically significant; for instance, doubling the number of spindles raises the estimated likelihood of the plant manager having previous experience managing another plant by 57.3 percent of the mean (36.0 percentage point increase with the mean of 62.8 percent; p-value=0.003), while it increases the likelihood of the manager being both educated and having previous experience by 77.2 percent of the mean ($p<0.001$). Also, doubling the number of spindles is associated with an increase in the likelihood that the manager allocated was subsequently promoted to an executive by 72.8 percent of the mean ($p=0.013$). The weakest association is observed between plant capacity size and higher education of the manager, but this may be because almost 80 percent of all the plant managers in our sample had higher education anyway, so there is little variation in this dependent variable.

While, as mentioned, not a strict test of Proposition 1, the results in Table 2 present strong suggestive evidence that there is indeed a positive assortative matching between plant size and managerial ability as we observe consistently positive correlations between relatively larger plant size and higher probability of that plant assigned a manager with higher education, prior experience of managing another plant, both these characteristics, or a future executive.

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[7] Both the number of plants and the number of individuals in our panel data were changing over time, as were many other aspects of both the internal and external environment surrounding the company. To control for all time-changing variables affecting the firm and the industry, we include time dummies in all regressions in this paper. We do not include plant or individual fixed effects for the most part because our focus is on the allocation of heterogeneous individuals across heterogeneous plants. We instead include plant location fixed effects to account for geographic variations in the distance in which (re-)allocation can happen. The location variable has four categories: Tokyo (only the Tokyo plant), Kansai region (seven plants), Kyushu region (five plants), and Okayama region (three plants). See Figure 1 for their locations.

[8] While the correlations across education, prior plant managing experience, and future promotion are all positive, they are not large, so they capture different aspects of managerial ability (see Appendix Table A1 for the correlation matrix).

Now, consider the case where a firm expands by adding a new plant, including but not limited to acquisition. For the first several years, the firm likely faces the task of integrating the new (acquired) plant into the firm, which often can be quite daunting (Capron & Mitchell, 2012). According to Proposition 2, we expect the firm to assign superior managerial talent to such new plants, at least temporarily, to facilitate integration into the firm culture and install its managerial practices. Moreover, this relationship should hold independent of capacity considerations in Proposition 1.

In Table 3, columns (1)-(4), we present the results of estimating a regression where the same proxies for the quality of the managers as in Table 2 are regressed on a dummy equal to one for the first five years of a new plant and zero otherwise.[9] The estimation equations once again include logged plant capital capacity and half-year and location fixed effects.

[Table 3 around here]

We do not find a statistical relationship in the simple indicator for the educated managers in column (1) of Table 3, but the first five years of new plants are, on average, positively associated with a higher probability of plant managers possessing the other three attributes that proxy for their quality. In particular, the first five years of new plants are associated with a higher likelihood of the manager being both educated and possessing experience in managing another plant by 0.189 points (37.5 percent of the mean; p=0.062). This underscores the importance of skilled managers' prior experience in newly added plants. Integration periods are also associated with the increase in the likelihood of appointing managers promoted in the future by 0.330 points (81.9 percent of the mean; p=0.047). Meanwhile, the coefficients on plant size are similar between Tables 2 and 3, suggesting that the "new plant effect" in Proposition 2 operates independently of the size effect in Proposition 1.

[9] When Muto took over the management of all plants owned by Kanebo in 1900, the company had just acquired three plants from other firms while it had two of its own incumbent plants—the Hyogo plant managed by Muto since he joined the company, and the Tokyo plant that had been outside of Muto's control until that time. We include the first five years of the Tokyo plant in the category of "new plants" because of strong evidence, noted below, that Muto faced an even bigger challenge in integrating the Tokyo plant into his management system than the plants just acquired from other firms.

As a "placebo test," we also examined whether the integration process of newly added plants required the allocation of high-level engineering talent—something that is not predicted by our theory. In columns (5) and (6), we use the logged number of educated engineers and the product of educated and experienced plant managers and educated engineers as dependent variables.[10] In contrast to plant managers, the results do not show positive correlations between the new plant dummy and the number of educated engineers allocated to the plant, either on their own or as a "bundled resource" with managers. Thus, while transplanting managerial practices by allocating high-quality managers was a key to integrating new plants into the firm, there was no need to allocate more engineering talent to such plants compared to other plants because technology was less of an issue.[11] Consistent with this, in Section 5.1 using individual-level data, we show that Kanebo replaced all managers in the acquired plants by its own managers but retained many of the educated engineers.

4.2 Product differentiation and three-way complementarity of managers, engineers/skilled workers, and high-end machines

Turning now to product differentiation, going beyond a simple, homogenous product requires purchasing machines specially designed for producing higher-count yarns as well as yarn-twisting and gassing equipment. If a plant is also to produce fabrics, it needs more specialized machines such as power looms and dyeing equipment. These specialized machines were high-tech for the Japanese industry at the time, so the firm needed relevant high-level human capital to operate them effectively.

High-level technical human capital was procured by hiring educated engineers from Imperial Universities (top-tier) and Technical Colleges (second-tier at the time; now equivalent to today's Institutes of Technology). In the first half of 1901, Kanebo only employed four educated engineers,

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[10] Here and in all cases below where a log transformation is employed for a variable that has some zero values, we adopt the inverse hyperbolic sine (IHS) transformation that better approximates a log function, especially at small values than the conventional employed, $ln(x+1)$. The IHS transformation is defined as $ln\left(x+\sqrt{x^2+1}\right)$.

[11] We also conducted sensitivity analysis using the first year and the first three years for new plants and the results were similar to those presented in Table 3. Those results are reported in Appendix Table A2.

none of whom was a university graduate. Five years later, right before it embarked on product differentiation, it still employed just 14 technical college graduates and eight university graduates (22 total educated engineers). By the first half of 1911, however, the total number of educated engineers employed by Kanebo more than tripled to 71, with 20 of them university graduates, and reached its peak of 111 (of which 29 were university graduates) in the second half of 1914, after which it leveled off. Kanebo also started to "build" the stock of skilled human capital by launching an internal vocational school in 1906, where lower-level workers were trained in specialized spinning skills.

From the resource allocation viewpoint, we expect the bundling of high-level engineering human capital and high-end, specialized machine. [12] Put it differently, in addition to the complementarity between plant size and managerial ability, product differentiation strategy also generated complementarity with educated engineers (Rubens, 2022). Thus, in product-differentiating plants, there is a three-way positive assortative matching between machines (especially specialized, higher-end machines), managerial, and engineering talent (Proposition 3 above).

Table 4 presents suggestive empirical evidence of this three-way complementarity using regression analysis. It displays estimation results where the dependent variables are the ability of the plant manager (proxied here by the manager having both formal education and previous experience managing another plant, although other proxies work similarly), the number of educated engineers in a given plant-semiannual observation in columns (1) and (2), and the interaction between these two variables (capturing the resource bundle comprised of a capable manager and educated engineers) in column (3). The dependent variables in the last two columns are the logged number of workers trained at its internal vocational school, and this number interacted with the same proxy for managerial ability.

[12] Skilled engineers were actually required already at the ordering stage for new machines. Japan was importing custom-made textile machinery from England at that time. Hand-written annotations on the orders the authors accessed in British archives bear witness to Japanese engineers participating in requesting special design features for machines ordered by their firms. See photocopies of original orders in the open data repository, Braguinsky et al. (2021a).

The independent variable of interest is the dummy set equal to one if the plant had specialized machinery (machines to produce counts above 20s, twisting and/or gassing machines, and/or power looms to produce fabrics) and zero otherwise. This dummy thus identifies plants that Kanebo designated to implement its product differentiation strategy. As before, the estimation equations also include logged plant capital capacity and half-year and location fixed effects.

[Table 4 around here]

The estimation results show that the allocation of capable managers and educated engineers tended to prioritize plants with specialized machines, even controlling for plant size and location. Plants possessing specialized machines were 33.4 percentage points more likely to have skilled managers (66.3 percent of the mean; p=0.086; column (1)) and have 91.4 percentage points more educated engineers (42.3 percent of the mean; p=0.008; column (2)) than those did not. Most tellingly, the coefficient on the specialized machines dummy in column (3), where the dependent variable is the "bundle" of educated and experienced managers and educated engineers, implies that plants with specialized machines had around 2.4 times more educated engineers (=$e^{1.215}$-1; p=0.013), in conjunction with a capable manager.

Turning to skilled workers, estimation results in column (4) indicate that plants with specialized machines have, on average, 40.6 percent more internally trained workers (=$e^{0.341}$-1; p=0.014) than those without. In column (5), we again see evidence of bundling them with capable managers, with 5.2 times more skilled workers (=$e^{1.821}$-1; p=0.044) in conjunction with a capable manager, suggesting that three-way complementarity extended to the non-engineering skilled workforce in plants conducting product differentiation.[13]

[13] The data on the allocation of internal vocational school graduates are available starting from 1908 which is why the number of observations in columns (4) and (5) is smaller than in the previous three columns.

The specifications in columns (3) and (5) use the weighted dummy variable for educated and experienced managers and the count variables for the number of engineers / internally trained workers. The product of these variables may not correctly capture three-way complementarity because if the manager does not have either higher education or prior experience (i.e., the manager dummy is zero), the dependent variables are always zero, regardless of the number of engineers or internally trained workers.[14] To alleviate this potential concern, in Appendix Table A3 we present a simple two-by-two tabulation of the number of observations by plants with and without specialized machines. Regarding managerial talent, plants are divided into those overseen by educated and experienced managers and those overseen by managers without higher education or previous experience managing a plant. Regarding engineering talent, the plants are divided into those above and below the median number of educated engineers. In plants with specialized machines, observations are heavily concentrated in the cell that has both educated and experienced managers and an above-the-median number of engineers (63.2 percent of observations are in this cell), while in plants with no specialized machines, 59.7 percent of observations are in the cell with a manager who does not possess either higher education or previous experience managing a plant, and a below-the-median number of engineers. Regression estimations using those median-cut dummy variables, reported in Table A4, produce similar results.

While the cross-plant (i.e., pooled OLS) regressions with time fixed effects presented in Table 4 fit our research design to compare the allocation of resources across heterogeneous plants at a given point in time, we also employed regressions using capital expansion events (i.e., machine orders) while including plant fixed effects to examine within-plant variations in human capital allocation following

[14] Suppose, just as an example, that the average number of engineers are five in product-differentiation plants and one in non-product-differentiation plants, regardless of the managers' quality. The manager dummy is one with the probability 0.5 and zero with the probability 0.5, regardless of product differentiation and engineers. In this case, the conditional mean of the dependent variable becomes 2.5 in product-differentiation plants and 0.5 in non-product-differentiation plants so that we find the positive correlation between the dependent variable and product differentiation, despite the fact there is no three-way complementarity. We thank Atsushi Ohyama for bringing this to our attention.

capital expansion. The results, presented in Appendix Table A5, confirm that we find within-plants three-way complementarity between managers, engineers, and high-end machines (though we do not find it for internally trained workers).

Finally, working with higher-level specialized machines helps develop the skills of engineers. These engineers can then be reallocated to other plants that introduce such machines later to apply their knowledge there (Proposition 4 above). In Table 5, we utilize the individual-level panel data on educated engineers to examine how the experience of working at a pioneering product-differentiating plant was associated with subsequent assignment to another plant conducting product differentiation later in the sample. More specifically, the dependent variable in columns (1)-(3) is a dummy equal to one if an engineer was transferred from a plant to another plant that was producing or later began producing differentiated products. The explanatory variable of interest is the dummy set equal to one if the engineer had previous experience working at one of the three plants that pioneered product differentiation strategy at Kanebo (the Tokyo, Hyogo, and Sumoto plants; see below Section 5.2 for more details). The estimation also controls for the total number of plants the engineer had worked at, as well as the (logged) capacity of the plant from which the engineer was relocating.

[Table 5 around here]

The results in columns (1)-(3) suggest that engineers' prior experience in pioneering product-differentiating plants is positively associated with the likelihood they were later reallocated to another product-differentiating plant. Specifically, in the most saturated specification in column (3), where we include controls for the number of plants the engineer had worked for before the focal transfer, the focal plant size, as well as individual, half-year, and plant location fixed effects, the corresponding association is estimated to be 9.8 percentage points (2.6 times the mean probability; p=0.001). As a placebo test, in columns (4)-(6), we employ the same regressions for the engineers' reallocation to a plant that did not produce differentiated products. In this case, we do not find an economically or statistically meaningful association between previous experience in a pioneering product-differentiating plant and the probability of reallocation, consistent with the claim that educated engineers carried their knowledge from experience in product differentiation to a different establishment also pursuing product differentiation.[15] These findings shed light on a possible channel of "spillovers" from product innovation to the overall growth in firm output noted in Braguinsky et al. (2021). Note also that controlling for individual fixed effects, the number of different plants the engineer had previously worked at positively affects the probability of another reallocation, both to a product-differentiating and a nonproduct differentiating plant (see the coefficients on the number of plants previously worked at in columns (3) and (5)).

5. Growth strategies and resource allocation: a deeper dive into historical evidence

In this section, we leverage historical data, in which Kanebo adopted different strategies at different periods, to examine the dynamics of resource allocation associated with each strategy. More specifically, our goal here is to deepen the understanding of the two-way and three-way complementarities revealed by the quantitative examination in the previous section through a "nano-economic" analysis of the ways in which (a) managerial talent was recruited and allocated to plants in need of being integrated into the company; (b) educated engineers were recruited and allocated to plants tasked with implementing the product differentiation strategy; and (c) human capital at various levels was recruited, trained and (re)-allocated as the firm became large and diversified.

Table 6 summarizes the transition of Kanebo's strategies and accompanying resource allocation in three different phases. From the late 1890s until about 1905, Kanebo's focus was on scaling the output of homogenous products, mostly through horizontal acquisitions, and the associated cost reduction (Yuki, 2014). Then, from 1906 to 1910, the primary focus switched to

[15] We also conducted another "placebo test" using the sample of engineers without formal education and confirmed that the relationships seen in Table 5 columns (1)-(3) do not hold in this sample either (see Appendix Table A6).

product differentiation. This sequencing was closely related to the fundamental "build or buy" growth dilemma (Capron and Mitchell, 2012). Through both these stages, Kanebo had to decide on how to procure the necessary human capital resources even before it could determine how to allocate them as its own internal resource base was yet inadequate. By the 1910s, however, the internal resource constraint had been by and large removed, allowing the firm to start pursuing a more balanced strategy consisting of both "build" and "buy." This new phase ushered in an increased emphasis on meeting changing plant-level needs through internal resource reallocation, as well as utilizing knowledge transfer from the highest-level educated engineers (university graduates) to second-tier educated engineers (technical college graduates) and skilled blue-collar workers. Such transfer allowed the firm to increasingly substitute technical college graduates and skilled workers for university-educated engineers. In what follows, we describe the resource acquisition and allocation decisions corresponding to each phase.

[Table 6 around here]

5.1 Cost-leadership, resource acquisition, and within-firm resource allocation

Kanebo's competitive strategy in the first phase was to increase output scale and achieve cost advantages for low-end (i.e., yarns of counts 20s and below) products. Horizontal acquisitions of struggling cotton spinners as the industry was going through the shakeout phase were an effective strategy to accomplish these tasks. In his essay, "On the Large Mergers of Cotton Spinners" (Muto, 1901), Muto went as far as to suggest that all Japanese cotton spinners should merge into a single trust to improve production efficiency:

> *"The fundamental spirit of 'Trust' [large-scale mergers – authors] … consists of merging separate businesses of the same kind to achieve capital concentration and sedulous management to lower production costs and prices, and thereby to increase capital profits and wages of workers working in production as well as provide cheaper goods for the public." (Muto, 1901, p.7; translated by the authors)*

This grand design never materialized, but Kanebo itself went on an acquisition spree.[16] Since most acquisitions consummated by Kanebo at this time were takeovers of plants run by poorly managed firms, the primary task was to improve the way the acquired plants had been operated.[17]

Muto recognized that human capital was the key to success (Kanebo, 1988). In particular, he gave substantial discretion to plant managers in plant operations, worker empowerment and retention, cost-saving, and quality controls (Yuki, 2013; see also Appendix C2.1-2.6). Since Kanebo did not yet have sufficient stock of high-level human capital, the primary need in this phase was the acquisition of skilled managers and engineers to whom Muto could entrust the task of operating the acquired plants. Table 7 summarizes the educational and previous experience backgrounds of plant managers and chief engineers in charge of Kanebo plants from 1900-1905 at the individual-semi-annual panel level. The total number of observations on plant managers is 108, while the number of unique individuals observed managing a plant at least once is 15. The corresponding numbers for chief engineers are 93 and 18, respectively.[18]

[Table 7 around here]

The major takeaways from Table 7 are four-fold. First, Kanebo did not rely on managers retained from acquired plants at all but rather allocated its own managers to them. This clearly reflects the need to radically overhaul operations by appointing new leadership that would implement the company's strategy and resolve the issues of integrating all plants into the new culture Muto wanted

[16] The series of acquisitions started in late 1899 when Kanebo acquired two middle-sized firms in Osaka and another firm on an island across the strait from its flagship plant in Hyogo in January 1900. Shanghai Spinners, a full subsidiary of Kanebo to begin with, was also formally acquired in 1899 and its facilities integrated into the Hyogo plant. This was followed in late 1902 by the acquisition of all firms that actively operated at the time on Japan's southernmost island of Kyushu (three firms and five plants total). See Table 1 for the details of the acquisitions consummated by Kanebo until 1920 (including later ones in 1907, 1911, and 1913) and Figure 1 for the geographic distribution of the company's plants.
[17] Muto took this task seriously and informed plant managers that the acquired plants lacked efficient operational practices and experienced staffs, so they needed to be resolved urgently (see Appendix C1.1-1.4).
[18] We focus on the number of observations because in some cases, Kanebo would appoint a manager to a newly acquired plant only to replace him within a year by a different one. Suppose the first manager did not have higher education while the second one did. Not weighing individuals by the number of periods they were in charge would lead to misleading results in such cases. Using the number of observations assigns weights to each manager corresponding to his tenure.

to install (see Appendix C1.1-1.2). However, Kanebo did not yet have a deep enough pool of own managers. The row "At Kanebo pre-1900" in the left panel of Table 7 shows that plant managers who had been with the company before 1900 were only 31 percent of the observations in this period. Thus, Muto had to procure the necessary resources from outside the firm.[19]

Second, most of the newly appointed managers (81 percent of all observations or 11 out of 15 unique individuals) had formal higher education, with degrees in economics or business.[20] College degree holders were a scarce resource during that era, and most firms did not have any cadres with higher education. Also, all degreed managers had graduated before 1900, so no freshly minted graduates were assigned as plant managers during those years. That underscores the importance of both managerial skills and experience as the firm faced the task of plant restructuring.

Third, Muto leveraged his network to acquire managerial talent. Muto himself graduated from Keio University, the first private university in Japan and the only one that provided education in practical managerial skills. More than half of the managers were drawn from the Keio alumni network. In particular, all the managers initially appointed to manage the three plants acquired in 1899-1900 were recent graduates from Keio University.[21] Muto also relied on the Mitsui network (around 27 percent of the observations), the business group that owned about 50 percent of Kanebo's shares during this period and where Muto himself had been employed prior to being transferred to Kanebo.

Significantly, the channels of acquiring engineering human capital during this period were very different from plant managers. To begin with, 31 percent of all observations on chief engineers (five out of 15 unique individuals) were those retained from acquired firms. Thus, while Kanebo wanted

[19] As can be seen from the last row in Table 7, we do not have information on the exact previous experience for 44 percent of all observations on plant managers, but there is no indication that any of those managers had worked at Kanebo prior to 1900, so in all probability, they also came from outside of the firm.
[20] It is possible that some among those for whom we do not know the education background also had higher education, so the estimate in Table 7 is conservative.
[21] After 1890, Keio University had economics, law/politics, and literature departments. All Keio graduates who became plant managers at Kanebo except one (Shingo Tsuda, who joined in 1907) hailed from the economics department. We thank Fukuzawa Memorial Center for Modern Japanese Studies, Keio University, for the data on graduation departments.

none of the acquired firms' management practices, it was willing to retain the technological expertise. Also, 47 percent of all observations are on chief engineers with no formal education (53 percent if we add those for whom we don't know for sure). Engineering talent available to the industry at that time, especially formally trained engineers, was still extremely scarce (Agarwal et al., 2020). In contrast to plant managers whose procurement heavily rested on university education and Muto's personal network, a large share of chief engineers was procured through hiring from competitors.

Even though the primary need in this stage was to procure the necessary resources to manage plant expansion, there were already some strategic (re-)allocations of managerial talent. As Kanebo acquired five more plants in 1902, the company immediately reallocated two of the managers in charge of previously acquired plants to the two largest and most important among the newly acquired plants, and one more such manager was reallocated to another newly acquired plant two years later. This corroborates Proposition 2 and regression results in Table 3. Also interestingly, we observe two managers, initially put in charge of acquired plants, promoted to manage the company's main plants in Tokyo and Hyogo, apparently in recognition of the work they had done with acquired plants. In particular, although technically not an acquisition, the Tokyo plant was in dire need of restructuring.[22]

The outcomes of this early strategy are presented in Appendix Figure A1. The first two panels depict the dynamics of two key metrics of the cost efficiency of production—the ratio of operating expenses to output and the ratio of wage expenses (total plant-level wage bill) to output measured in weight units (pounds), adjusted to the 20s count as in Braguinsky et al. (2021). The data are aggregated by three categories of plants: Kanebo's own Tokyo and Hyogo plants, the three plants in the Kansai region acquired in the late 1899-early 1900, and the five Kyushu plants acquired in 1902 (see Appendix

[22] The plant manager in charge of this restructuring, Masazumi Fuji, was relocated to the Tokyo plant after a brief stint at an early acquired plant. Fuji had graduated from Keio University and overlapped with Muto at Mitsui bank in 1893-94. He then joined Kanebo as a middle manager in 1897 (Mita Shogyo Kenkyukai, 1909, pp. 645-646). Once in charge of the Tokyo plant, Fuji implemented various managerial innovations, from improving machine maintenance and working conditions to such small but important things as leveling the plant floor to avoid wasting lubricating oils (Kinugawa, 1939, pp. 476-483; cf. Bloom et al., 2013). Fuji was rewarded by being promoted to the company Board of Directors in 1907.

Figures A2 and A3 for each plant separately). We observe a rapid decrease in both operating expenses to output and wages to output ratios across all plants, but especially in acquired plants after acquisitions, resulting in almost full convergence by around 1904 (see also Yuki, 2013).[23]

Improved management practices can also be seen in large reductions in worker turnover (quit) rates, which was a serious problem as it hindered human capital accumulation.[24] Panels C and D in Figure A1 show that both Kanebo's original plants and acquired plants (post-acquisition) succeeded in reducing turnover rates, with an average decrease rate of over 50 percent over 1900-1905 (see Appendix Figure A5 for each plant separately).

5.2 Product differentiation, resource building, and within-firm resource allocation

The second phase of Kanebo's growth strategy started around 1906 and continued until 1910. During this period, the focus shifted from scale expansion and cost reduction to upgrading and diversifying the product portfolio. This strategic shift was due to the realization by the company's top brass that there were immense unexploited profitable opportunities in the markets for finer, higher-quality, and more processed yarn, such as gassed yarn, as well as in mechanized fabric production. The first major decision taken by the company in the second half of 1906 was to procure brand-new machines to produce yarns of high counts (60s and 80s), as well as yarn gassing equipment for its newly restructured Tokyo plant. The decision to prioritize this project among a slew of others (see Appendix C4.1) was based on the recognition of its high profitability seen in the letter sent by Muto to all plant managers:

> *"We are rushing full operation of the Tokyo plant No. 3 [the high-count yarn plant] because the profitability of gassed yarn is high. I would like all plant managers to understand this goal." (Shihainin Kaisho, 02/02/1908; translated by the authors)*

[23] For example, the pre-acquisition rates of operational and wage expenses in the acquired plants in Kyushu were respectively 53.2 percent and 35.9 percent higher than in the original plants, while those gaps decreased to 16.0 percent and -0.002 percent after acquisition. Appendix Figure A4 shows that the decline in wage expenses to output ratio did not come from lower wages; instead, this decline resulted from improved productivity accompanied by higher, not lower wages.
[24] Worker turnover was a serious problem for all Japanese cotton spinning firms at that time (Saxonhouse, 1974). Recognizing that high worker turnover rates hindered the accumulation of skilled human capital, Muto repeatedly instructed plant managers to improve worker retention (see Appendix C3.1-3.7).

In February 1908, Kanebo placed three orders for new machines designed to produce middle-count yarns (up to 45s count) in the Sumoto plant that tripled and drastically upgraded its capacity. This plant also diversified downstream by adding loom machines to produce fabrics. The next year Kanebo's flagship plant in Hyogo diversified downstream and added some more spindles, and so did the two formerly acquired plants in Kyushu, Nakatsu (downstream diversification in 1909) and Hakata (downstream diversification and middle-count yarn producing machines added in 1910).

At this stage, Kanebo did not add any new plants through acquisitions, so the firm could now focus more on (re-)allocating its internally accumulated managerial resources in accordance with the new strategic priorities. Table 8 presents the characteristics of plant managers during the second phase, comparing plants that were conducting product differentiation to those that at this stage were only producing low-end products and not (yet) part of implementing the product differentiation strategy. The first thing to note is that in all observations on plants conducting product differentiation, plant managers were formally educated ones, with 85 percent of those being Keio University graduates, as opposed to just 45 percent of Keio University graduates in other plants. Product-differentiating plants were also assigned experienced managers: in 78 percent of observations on such plants, managers had worked for Kanebo prior to 1906, compared to just 20 percent in other plants. Thus, the cadres chosen to oversee the beginning of the product differentiation strategy implementation were managers who were both educated and experienced (see also Table 4 above).

[Table 8 around here]

Second, and in contrast to the previous phase, the assignment of educated and experienced managers to plants selected for product differentiation was largely accomplished through internal reallocation. The data presented in Table 8 show that in 70 percent of observations, pioneering plants involved in product differentiation were assigned managers with previous experience at another plant. For instance, as aforementioned Masazumi Fuji (see footnote 22) was promoted to the company board of executives in 1907, he was replaced by the manager who had been in charge of the largest plant among those Kanebo acquired from Kyushu Spinners in 1902 (and also a Keio University graduate). Another experienced manager with a Keio University degree who had overseen a plant Kanebo acquired in 1899 was relocated to manage the Sumoto plant in 1907, right before it started upgrading its capacity as mentioned above. Yet another manager with experience in managing a previously acquired plant was sent to manage the upgrading at the Nakatsu plant in 1909.

Implementing the new strategy also involved non-trivial technological challenges, which required expanding and upgrading not just the stock of machines but also the stock of engineering human capital and skilled operatives. In contrast to managerial resources, Kanebo's stock of educated engineers at the start of the product differentiation strategy was still quite thin, and Kanebo had no internal worker training facility yet. During 1906-1910, the firm more than tripled the number of degreed engineers it employed, mostly by hiring new graduates of Imperial Universities and Technical Colleges. It also reallocated skilled blue-collar workers to plants tasked with product differentiation.

Figure 2 shows the allocation of educated engineers across plants implementing product differentiation at this stage and other plants. Plants conducting product differentiation on average had 1.4 degreed engineers in senior positions compared to 0.6 engineers in other plants. Furthermore, plants that conducted product differentiation were prioritized compared to other plants in assigning degreed engineers at all levels, engineers hired out of school (those who graduated in 1905 or later) and those with experience working for Kanebo before this period (although in the latter case the 95-percent confidence intervals largely overlap). The aforementioned Sumoto plant serves as a case in point: it had no degreed engineers until 1902 and only one such engineer for several more years. As it was selected for product differentiation around 1909, however, the firm immediately assigned five degreed engineers to this plant, increasing to 10 by 1911.

[Figure 2 around here]

In addition to hiring educated engineers out of universities and colleges (i.e., "buying" specialized human capital), Kanebo also embarked on "building" its own stock of skilled blue-collar workers by launching its internal vocational school in 1905. The school sought applicants from all the Kanebo's plants and trained them in advanced spinning skills under a one-year program.[25] Despite high turnover rates, this school had increased the stock of lower-level skilled human capital (Appendix Figure A6), with evidence that plants conducting product differentiation were prioritized in allocating those workers, as well as educated engineers (Table 4 above; see also Appendix Figure A7).

Interestingly, the shift to product differentiation appears to have forced the company to set aside, at least temporarily, the goal of reducing operating expenses. Recall that the ratio of operating expense to output went down dramatically in the previous phase (see Appendix Figure A1 and Appendix C1.3-1.4). This trend was completely reversed in this new phase until it was brought somewhat under control in 1910 (Appendix Figure A8). Changes in company operations accompanying product differentiation may have partially contributed to this. For instance, high-end machines likely required more frequent and expensive maintenance (see Appendix C5 for some suggestive evidence). They also needed raw cotton inputs imported from the U.S. and Egypt rather than Chinese or Indian cotton.[26] Also, higher-count (thinner) yarn presumably requires more packaging and shipping expenses per same weight.

5.3. Balanced growth strategy and complementarity of resources

The third and final phase we analyze in this paper covers the period from 1911-1918. A major difference from the first two stages was that by this time, Kanebo had internally accumulated substantial stocks of both managerial and engineering human capital. This allowed the firm to pursue

[25] The curriculum included classes of mixing, blowing, carding, first spinning, fine spinning, and finishing (bundling), and the use of machines. The detailed guidelines disseminated to plant managers for its launch are described in Appendix C5.1. Appendix C5.2 shows that the curriculum was constantly updated in response to the deficiency of necessary skills.
[26] While cotton input is not part of operating expenses, delivery costs are.

growth along multiple dimensions, from continued product upgrading and diversification to new plant construction through more acquisitions, and to allocate and reallocate internal resources in doing so.

The key focus remained on expanding the variety of the product portfolio, but rather than breaking into some even newer product spaces, the firm focused on expanding the overall output scale while steadily increasing the share of high value-added high-count and processed yarn. As seen in Figure 3, in 1910, the combined share of yarn of counts above 20s (i.e., middle-end plus high-end products) was still only about 30 percent of total output. This had increased to almost 60 percent toward the end of our sample. Most pronounced was the growth in middle yarn counts (from 21s to 51s), which almost caught up with the output of low-end yarns by 1918. The number of new product varieties in this "middle range" also rapidly increased (Braguinsky et al., 2021).

[Figure 3 around here]

The increase in high-count and middle-count output was achieved both by adding new, high-end machines to existing plants and by acquisitions. Kanebo installed such machines in its flagship Hyogo plant in 1913, with the capacity of one-third of its pre-existing, low-end machine capacity. The firm also constantly kept purchasing more high-end machines for the Sumoto plant, whose production scale of middle yarn counts became 2.45 times larger than its low-end production by 1918. However, other plants, including the brand-new Takasago plant, remained in the low-count product space and did not engage in downstream diversification either (see Table 1).

The change in the nature of acquisitions is especially noteworthy—while increasing production efficiency through improved management remained a goal, Kanebo started targeting plants that would increase its capacity to produce diversified products. In 1911, Kanebo acquired four plants in the western part of Honshu operated by Kenshi Spinners and a plant in Osaka owned by Asahi Spinners & Weavers in 1913. As seen in Table 1, most of those newly acquired plants already had high-end machines and looms for producing fabrics installed by the previous owners. Especially the Osaka plant was brand-new as its previous ownership acquired all the high-end machines and looms in 1912-13 but could not start operations and instead sold the plant to Kanebo. In its turn, Kanebo added high-end yarn production to the Saidaiji plant and expanded both the low-end and high-end production capacity of most plants it acquired. Also, in conjunction with the launch of operations by the Osaka plant in 1915, it built a specialized dyeing and finishing plant nearby (the Yodogawa plant, not listed in Table 1 because it did not produce any yarn or fabrics on its own).

By that time, Muto had a lot of personnel to choose from to manage important new plants such as this Yodogawa plant. In this case, the choice fell on Shingo Tsuda, a maverick Keio graduate who first joined the company in 1907 as a rank-and-file worker and later oversaw the expansion of the Saidaiji plant after being appointed to manage it in 1911. According to Tsuda's biography:

> *"Kanebo needed a large-sized plant for dyeing and finishing for its future growth … Muto planned to construct a large-scale plant that could surpass British plants. Accordingly, the construction of the Yodogawa plant required new knowledge and an outstanding and capable person. … Tsuda was eventually chosen for this role following several rounds of selection." (Ishiguro, 1960, p. 60; translated by the authors)*

Thus, the selection of managers was indeed a product of the top manager's deliberate decisions, and Tsuda was selected for his capabilities. He later went on to become the second company president.

There are various instances where educated managers with prior experience in managing plants where they already oversaw product differentiation were reallocated to newly acquired plants tasked with expanding the scope of Kanebo's product portfolio. For example, Toshijiro Sato, a graduate of Keio University who oversaw the upgrading and diversification of the Sumoto plant (one of the pioneering plants tasked with product differentiation), was appointed to manage the two largest plants among those acquired from Kenshi Spinners in 1911 and oversaw a big expansion of the high-end capacity in one of those. Another Keio-educated and experienced manager, Gota Miyake, who oversaw the launch of the weaving division and middle-count yarn market penetration in the Nakatsu plant in 1909-1913, was put in charge of the newly acquired Osaka plant in the second half of 1913 and oversaw the launch of its operations. Both Sato and Miyake were later promoted to executive positions in the company. On the contrary, plants not involved in product differentiation were still often assigned managers without any previous managerial experience and higher education (such as the Wakayama plant, also acquired from Kenshi spinners alongside other three plants but tasked with low-end yarn production). These individual cases illustrate that talented managers with relevant experiences were selectively allocated to priority plants.

Turning to the allocation of engineering talent, Figure 4, Panel A shows that while plants that conducted product differentiation generally had more university-educated engineers per plant than plants not involved in product differentiation, their employment was concentrated in the early years (when product differentiation was just starting) while such engineers were later released.[27] In contrast, as can be seen in Panel B, employment of technical college graduates (also educated engineers but with less prestigious education and thus significantly cheaper than university graduates) picked up in plants conducting product differentiation a little later but remained at a high level throughout our sample. Finally, Panel C shows that the number of internally trained skilled workers kept increasing in both plants, while the levels remained much higher for the former plants.

[Figure 4 around here]

How can we interpret these dynamics? Why did university-educated engineers decline in the 1910s while technical college-educated engineers and internally trained workers remained at high levels? One explanation, which would be consistent with knowledge transfer from product upgrading to product diversification (Braguinsky et al., 2021), could be as follows. New technologies require the highest-level human capital (embodied in university-educated engineers), especially when they are just

[27] The first peak in the number of university-educated engineers in 1906-1909 corresponds to the initial phases of introducing high-end machines and looms in pioneering product-differentiation plants (Tokyo, Sumoto, Hyogo), while the second peak around 1913-1915 corresponds to product differentiation involving plants acquired in 1911-1913 mentioned immediately above (with the Osaka plant actually starting operations in 1915).

being introduced. However, as such technologies become more familiar and the novel production process becomes routinized, the knowledge can now be transferred within establishments to lower-level engineers and even to skilled blue-collar workers who become technologically competent enough to run the production process on their own. Such knowledge transfer enabled university-educated engineers (and partly technical college-educated engineers) to be released and/or reallocated to other plants.[28] Consistent with this notion, Appendix Figure A9 shows that within each pioneering plant—Tokyo, Hyogo, and Sumoto, the number of university-educated engineers assigned did not increase and even declined a few periods after the initiation of product differentiation, while the number of technical college graduates and skilled workers kept increasing. Appendix Table A7 summarizes the allocation of the educated engineers after their appointment to the pioneering plants. It shows the general pattern of reallocation from a pioneering plant to another product-differentiating plant.

6. Conclusion

Using detailed plant- and individual-level panel data from a major Japanese cotton spinning company over the first two decades of the 20th century, we showed that there was two-way complementarity between managerial talent and important plants when the strategic task was achieving large-scale output and positioning for a competitive cost advantage. The task of conducting product differentiation, however, required bundling high-end machines (specialized physical capital) with highly skilled (educated) engineering human capital while still requiring the assignment of the most capable (educated and experienced) managers, giving rise to a "three-way complementarity" between machines, managers, and engineers (as well as skilled workers).

Leveraging the unique historical nature of our data, we dug deeper into the "nano-economics" of resource allocation associated with each strategy. The clear contrast is that in the earlier period, the

[28] For instance, as mentioned, while the Sumoto plant constantly expanded its high-end machines over the years, the number of university-educated engineers reached the peak of three in 1910-11 and subsequently fell to just one by 1913. However, the number of technical-college educated engineers grew to nine by 1913 and then stayed at this level.

firm only had a meager internal resource base and thus had to pursue the two strategies above one by one, while in the later period, the firm had accumulated an adequate internal resource base and could pursue both strategies at the same time. This analysis further uncovered that (i) the firm paid special attention to recruiting and allocating the right kind of managerial resources to new plants that needed to be integrated into the firm; (ii) the initial phase of product differentiation strategy entailed building up the stock of highly educated engineers and allocating them to pioneering plants conducting product differentiation in conjunction with the best managers; and (iii) once the initial difficulties of mastering high-end technologies had been overcome, knowledge embodied in the most capable engineers hired from Imperial Universities could be transferred to second-tier engineers and internally trained skilled workers who could then substitute for expensive university-educated engineers.

Our research setting has a limitation in that it rests on a single firm case. While we leverage a unique opportunity to highlight the dynamic transition of the allocation process in different growth phases, the generalizability to a different industry, country, and time remains an open question. Moreover, all managers and engineers in our data are Japanese males, so we only observe heterogeneity in terms of educational background and job experience. Future studies dealing with more diverse samples in terms of demographics can shed light on how firms allocate human capital considering multiple facets of human capital.

Decisions about human capital (re-)allocation are, of course, part of a broad strategy decision-making process. In line with the call for papers for this special issue, we highlighted the endogenous process of the firm's resource allocation decisions in conjunction with physical capital investment and strategic implementation. If the focus is on empirical identification, future studies may leverage exogenous sources of variation that force internal human capital to be transferred to explore the interaction of different kinds of resources and their consequences. Such "forced" (re-)allocation of resources due to factors outside of the firm's control, however, may have very different consequences compared to deliberate (strategic) allocation decisions. We believe that in studies like this, endogeneity of the resource allocation process should be embraced as part of the mechanism of interest.

This paper makes several contributions to the resource allocation literature. First, we fill the gap in this literature by providing empirical evidence on the allocation of different kinds of skilled human capital (plant managers, engineers, and skilled workers) within a single-industry firm (Ahuja & Novelli, 2016; Maritan and Lee, 2017). In doing so, we highlight complementarities at the plant level between physical capital related to new product markets and human capital with relevant skills. Using machine orders data, we show that skilled human capital was particularly relevant for plants conducting high-end capital expansion. While the complementarity between skilled human capital and new technologies has been previously documented (Stadler et al., 2021; Rubens, 2022), we particularly highlight the three-way complementarity of managers, engineers, and new technologies in product differentiation in which skilled managers and engineers were likely to be allocated in tandem.

Second, our paper contributes to the stream of the literature employing historical methods in strategy research (Ingram et al., 2012; Kahl et al., 2012; Murmann, 2012; Argyres et al., 2020; Pillai et al., 2020). Specifically, we show the usefulness of historical methods in studying resource allocation. We leverage the "nano-economic" approach to identify each individual manager and engineer's educational backgrounds and prior job experience to shed light on the allocation process of heterogeneous human capital across different establishments (Braguinsky and Hounshell, 2016).

Our study tells the story of Kanebo's internal resource allocation, starting with the period when it only had two plants producing simple basic products, with a narrow and limited stock of both machines and human capital. We follow it through a remarkable journey involving growing scale and number of establishments, expanding the firm's technological frontier, and building up and (re-)allocating managerial, engineering, and skilled labor resources required to make this multifaceted expansion possible. In retrospect, Kanebo's was an amazing accomplishment. The granular data employed in this study allows us to unpack the endogenous resource allocation process that led to Kanebo becoming one of the most important firms in this critically important industry.

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Figures and Tables

Figure 1: Location of Kanebo's plants

Panel A: Ten plants built or acquired in 1887-1902

Panel B: Six plants built or acquired in 1907-1913

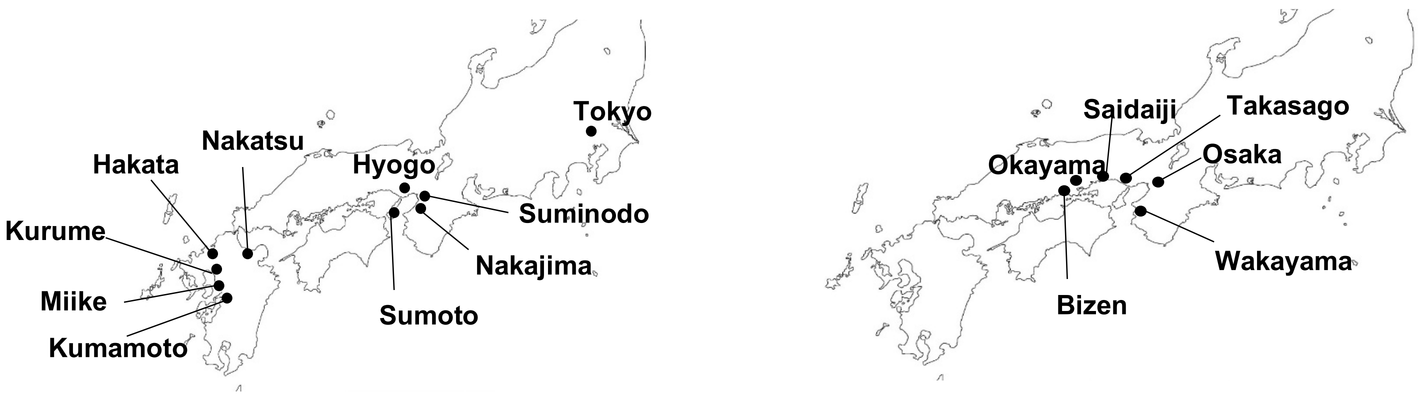
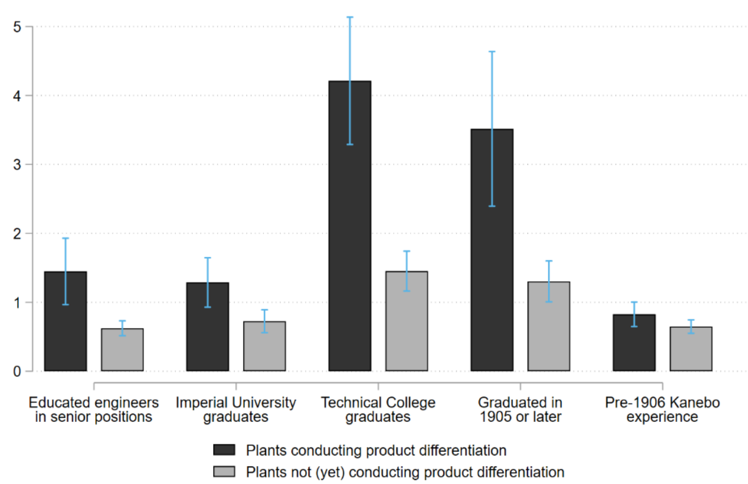
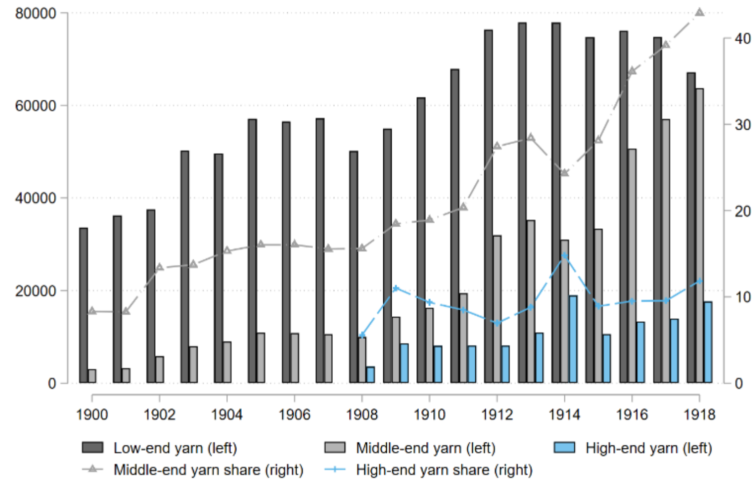


Figure 2. Number of engineers per plant-semiannual observations by plants conducting product differentiation or not, 1906-10



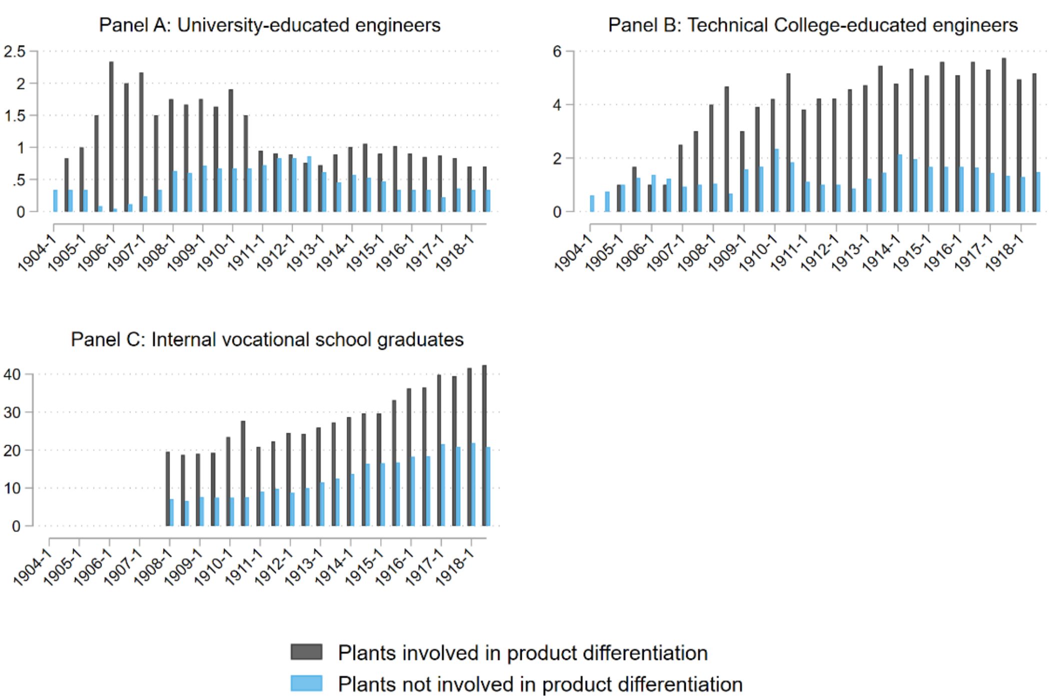
Note: The blue lines are 95% confidence intervals of the sample means.

Figure 3. Kanebo total output by type of yarn.



Note: The figure depicts the count-adjusted total amount of output (in pounds) in each category. "High-end yarn" are counts 52s and higher. "Middle-end yarn" are counts 21s-51s. "Low-end yarn" are counts 20s and below.

Figure 4.
Educated engineers and workers in plants involved and not involved in product differentiation.



Note: In all panels, each bar represents the number of engineers/vocational school graduates per plant across plants that conducted or did not conduct product differentiation.

Table 1: Summary of Kanebo's plant history from the 1880s to the 1910s.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Plant	Year of launch /acquisition	Built or Acquired	Acquired firm	Initial capacity of spindles	Capacity in 1918-2	Capacity change (%)	High-end yarn production	Downstream integration
Tokyo	1887	Built	-	28,920	78,040	169.8	1908-2	1912-1
Hyogo	1894	Built	-	40,000	97,296	143.2	1913-1	1905-2
Suminodo	1899	Acquired	Kashu Spinners	10,368	10,752	3.7	-	-
Nakajima		Acquired	Kunijima Spinners	10,368	19,184	85.0	-	-
Sumoto	1900	Acquired	Awaji Spinners	10,368	37,276	259.6	1909-1	1909-1
Miike	1902	Acquired	Kyushu Spinners	31,104	30,720	-0.01	1902-2	-
Kurume				14,760	15,528	5.2	-	-
Kumamoto				10,368	10,752	3.7	-	-
Nakatsu		Acquired	Nakatsu Spinners	10,368	10,752	3.7	-	1909-2
Hakata		Acquired	Hakata Kenmen Spinners	11,136	11,904	6.9	1910-2	1910-2
Takasago	1907	Built	-	22,420	37,440	67.0	-	-
Okayama	1911	Acquired	Kenshi Spinners	13,376	14,528	8.6	-	pre-acquisition
Wakayama				11,136	11,136	0	-	-
Bizen				36,668	43,884	19.7	pre-acquisition	-
Saidaiji				7,936	11,072	39.5	1912-2	pre-acquisition
Osaka	1913	Acquired	Asahi Spinners & Weavers	28,456	31,756	11.6	pre-acquisition	pre-acquisition

Notes: "Capacity change" shows the change rate from the initial capacity to the capacity in 1918-2. The columns "High-end yarn production" and "Downstream integration" show the timing (year-half period) when high-end spindles or looms (for textiles) were actually installed in a plant, and missing cells mean that high-end production or downstream integration was never conducted until 1918-2. Only cotton-spinning plants are listed in the table, while those specialized in silk are not. Two other acquisitions are not listed in this table: Shanghai Spinners (19,840 spindles) integrated into the Hyogo plant, and Nihon Kenmen Spinners & Weavers (20,708 spindles) integrated into the Sumoto plant.

Table 2. Positive assortative matching between managerial quality and plant capacity size ("two-way complementarity")

VARIABLES	(1) Educated plant manager	(2) Experienced plant manager	(3) Educated and experienced plant manager	(4) Manager promoted in the future
Logged plant capacity	0.089	0.360	0.389	0.243
	(0.070)	(0.100)	(0.078)	(0.087)
Constant	-0.016	-2.948	-3.302	-2.049
	(0.771)	(1.109)	(0.857)	(0.943)
Observations	452	452	452	452
R-squared	0.110	0.321	0.358	0.170
Half-year FEs	Yes	Yes	Yes	Yes
Plant location FEs	Yes	Yes	Yes	Yes
Mean DV	0.800	0.628	0.504	0.334

Notes: Educated manager is an indicator of whether a plant manager had higher education. Experienced plant manager is an indicator of whether a plant manager possesses prior plant manager experience. Manager promoted in the future is an indicator of whether a plant manager was promoted to an executive position later in Kanebo. Estimation method: OLS. Robust standard errors clustered at the plant level in parentheses. Plant capacity is measured as the total number of spindles.

Table 3. Allocation of managerial talent to newly added plants

VARIABLES	(1) Educated plant manager	(2) Experienced plant manager	(3) Educated and experienced plant manager	(4) Manager promoted in the future	(5) Log(# of educated engineers)	(6) Log(Educated plant manager x # of educated engineers)
1(First five years of a new plant)	-0.001	0.143	0.189	0.330	-0.291	-0.162
	(0.089)	(0.122)	(0.094)	(0.152)	(0.230)	(0.274)
Logged plant capacity	0.089	0.375	0.408	0.500	0.707	0.784
	(0.068)	(0.090)	(0.076)	(0.135)	(0.147)	(0.215)
Constant	0.134	-3.982	-4.268	-4.973	-6.823	-7.524
	(0.786)	(1.013)	(0.855)	(1.890)	(1.988)	(2.731)
Observations	452	452	452	452	452	452
R-squared	0.110	0.330	0.374	0.326	0.655	0.456
Half-year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Plant location FEs	Yes	Yes	Yes	Yes	Yes	Yes
Mean DV	0.800	0.628	0.504	0.403	1.533	1.293

Notes: Estimation method: OLS. Robust standard errors clustered at the plant level in parentheses. The explanatory variable is a dummy equal to one if the first five years of a new plant. Plant capacity is measured as the total number of spindles. The logged dependent variables are based on the inverse hyperbolic sine (IHS) transformation: $y = ln\left(x + \sqrt{x^2 + 1}\right)$.

Table 4. Three-way complementarity between managers, educated engineers/skilled workers, and specialized production machines.

VARIABLES	(1) Educated and experienced plant manager	(2) Log(# of educated engineers)	(3) Log(Educated and experienced plant manager X # of educated engineers)	(4) Log(# of internal vocational school graduates)	(5) Log(Educated and experienced plant manager X # of internal vocational school graduates)
1(Specialized machines)	0.334	0.649	1.215	0.341	1.821
	(0.181)	(0.214)	(0.433)	(0.123)	(0.827)
Logged plant capacity	0.256	0.478	0.563	0.651	1.195
	(0.110)	(0.165)	(0.261)	(0.158)	(0.550)
Constant	-2.172	-3.481	-5.095	-3.070	-10.749
	(1.049)	(1.582)	(2.468)	(1.544)	(5.153)
Observations	452	452	452	291	291
R-squared	0.411	0.704	0.609	0.725	0.523
Mean DV	0.504	1.533	0.995	3.603	2.215

Notes: Estimation method: OLS. All models include half-year and plant location fixed effects. Robust standard errors clustered at the plant level in parentheses. Specialized machines dummy is a dummy equal to one if the plant had machines for higher yarn counts and/or looms. The logged dependent variables are based on the inverse hyperbolic sine (IHS) transformation: $y = ln\left(x + \sqrt{x^2 + 1}\right)$.

Table 5. Experience at a pioneering product-differentiation plant and relocation of educated engineers.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	1(Transferred to a product-differentiating plant)			1(Transferred to a non-product-differentiating plant)		
1(Experience at a pioneering product-differentiating plant)	0.021	0.135	0.098	0.008	0.017	0.017
	(0.012)	(0.031)	(0.028)	(0.014)	(0.028)	(0.034)
Number of plants previously worked at			0.094			0.063
			(0.013)			(0.014)
Logged plant capacity			0.010			-0.034
			(0.002)			(0.005)
Constant	0.027	-0.026	-0.178	0.035	0.031	0.363
	(0.005)	(0.015)	(0.027)	(0.008)	(0.013)	(0.061)
Observations	1,580	1,575	1,574	1,580	1,575	1,574
R-squared	0.036	0.132	0.182	0.051	0.114	0.182
Individual FEs	No	Yes	Yes	No	Yes	Yes
Mean DV	0.037	0.037	0.037	0.039	0.039	0.039

Notes: Individual-level panel data on university- and technical college-educated engineers. Estimation method: OLS. All models include half-year and plant location fixed effects. Robust standard errors clustered at the individual level in parentheses. Pioneering product-differentiating plants are Tokyo, Hyogo, and Sumoto plants.

Table 6. Transition of Kanebo's key strategies and human capital allocation

	Phase I (1890s-1905) "Buy" growth strategy	Phase II (1906-10) "Build" growth strategy	Phase III (1911-18) Balanced strategy
Number of plants (excluding silk-production plants)	2 original plants + 8 acquired plants	10 existing plants + 1 original plant	11 existing plants + 5 acquired plants
Competitive strategy and product type	• Cost-leadership • Low-end, homogeneous yarns	• Begin product differentiation in a few of the plants ○ High-end yarns ○ (e.g., double, twisted yarns) ○ Textiles (downstream)	• Simultaneously pursue both cost-leadership and product differentiation • Expand production scales of high-end products
Growth strategy	• Acquisition of cotton-spinning firms • Hiring managers using Muto's network • Hiring university-graduated managers and engineers	• Capital investment for product differentiation • Purchase of high-end production machines • Internal training school for blue-collar workers	• Acquisition of cotton-spinning firms • Capital investment for product differentiation • Internal training school for blue-collar workers
Human capital (re-)allocation	• Allocate talented managers to large plants (two-way complementarity) and plants that needed efficiency improvement • A few talented managers to the most strategically important plants	• Allocate educated managers and skilled engineers/workers to plants conducting product differentiation (three-way complementarity)	• Allocate educated managers to acquired plants to improve operational efficiency (two-way complementarity) • Allocate educated managers and skilled engineers/workers to plants conducting product differentiation (three-way complementarity) • Reallocate educated managers and engineers who experienced product differentiation in pioneering plants to other plants also conducting product differentiation

Table 7. Managers and chief engineers of Kanebo's plants, 1900-1905

	Plant managers			Plant chief engineers		
	# of observations	Share	Excl. unknown	# of observations	Share	Excl. unknown
All	108	1.00		93	1.00	
Retained from acquired	0	0.00		29	0.31	
Education:						
Keio University (economics,	62	0.57	0.71	0	0.00	0.00
Imperial University	0	0.00	0.00	17	0.18	0.20
High Commerce Schools	19	0.18	0.22	0	0.00	0.00
High Technical School	6	0.06	0.07	26	0.28	0.30
Graduation cohort: 1900 or	0	0.00	0.00	13	0.14	0.15
No formal education				44	0.47	0.51
Unknown	21	0.19		6	0.06	
Previous experience:						
Worked with Muto	33	0.31	0.54	3	0.03	0.03
At Kanebo pre-1900	33	0.31	0.54	19	0.20	0.22
Mitsui network	29	0.27	0.48	2	0.02	0.02
Industry experience	50	0.46	0.82	74	0.80	0.85
Competitor experience	12	0.11	0.20	38	0.41	0.44
Unknown	47	0.44		6	0.06	

Notes: The unit of observation is the individual-semiannual period. The number of individuals in charge of a plant in at least one semi-annual period is 15 managers and 18 chief engineers. Previous experience types are not mutually exclusive, so the total does not sum up to 100 percent.

Table 8. Managers of Kanebo's plants, 1906-1910

	Plants conducting product differentiation		Plants not (yet) conducting product differentiation	
	# of observations	Share	# of observations	Share
All	27	1.00	94	1.00
Education:				
Keio University (economics, etc.)	23	0.85	42	0.45
High Commerce Schools	4	0.15	26	0.28
No formal education/unknown	0	0.00	26	0.28
Previous experience:				
At Kanebo pre-1906	21	0.78	19	0.20
Transferred from another plant	19	0.70	66	0.70
Mitsui network	10	0.37	8	0.09

Notes: The unit of observation is the individual-semiannual period. Observations on plants conducting product differentiation (six managers): (i) Tokyo plant, 1906-10; (ii) Sumoto plant, 1908-10; (iii) Hyogo plant, 1909-10; (iv) Nakatsu plant, 1909-10; (v) Hakata plant, 1910. Other observations (15 managers) on plants not (yet) conducting product differentiation. Previous experience is not mutually exclusive, so the total does not sum up to 100 percent.