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Abstract

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1. Introduction

The corporate headquarters (HQs) of firms manage production plants of different sizes. However, large production plants are likely to require separate HQs, as they need a wide variety of corporate services. A plant with a large number of workers might also necessitate that the HQ be collocated with the plant to ensure direct management by plant managers. Decreasing returns to scale in production or in management would warrant either an independent HQ or the splitting of production across multiple plants. While HQ tends to be concentrated in agglomerated core regions, production should be divided across plants in different locations to save costs of production and/or transport. Separating the HQ or splitting production across multiple plants are corporate decisions that involve serious trade-offs.

These issues are important also for understanding real-world problems. As examined by Duranton and Puga (2005), firms recently fragment production processes and locate various activities in different regions, and HQ functions are increasingly concentrated in core regions such as Tokyo in Japan. Consequently, it will be informative if we characterize how plants operated by firms with HQs in different locations (possibly in urban core) and plants operated as a part of multi-plant operation differ from plants collocated with HQs in terms of employment, wage and productivity.

This paper investigates how these *corporate* organizational decisions of production interact with the *spatial* organization of production (plant locations) as well as *industrial* organization factors (e.g., plant size). On the one hand, because of rich opportunities for outsourcing corporate services available in regions near agglomerated cores, the HQ is located away from the production plants. On the other hand, firms geographically distribute their production plants over peripheral regions in order to save transport costs for serving the respective local markets. However, the constraint on internal resources, such as management capability, is likely to make the smaller plants more vulnerable to the remoteness from agglomeration.

While previous research (reviewed in the next section) is largely based on firm-level or aggregate data, this paper derives plant-level panel data from Japan's *Annual Survey of Manufacturers*. This paper finds that large-sized plants tend to be separated from their HQs and operated by multi-plant firms. Plants located far from the core regions are likely to have separated HQs and to be a part of multi-plant operations. Our principal findings are robust in panel data format even after controlling for firm-specific effects or checking the consistency with dynamic patterns such as entry and plant-type switches.

The rest of this paper is organized as follows. Section 2 reviews related literature. Section 3 describes the plant-level panel data used in the study. Section 4 explains the empirical specifications and reports the estimation results on HQ separation. Similarly, Section 5 presents the results on multi-plant operation. Section 6 checks the robustness of our results by examining dynamic aspects: entry of new plants, and switches of plant status. Finally, Section 7 presents the concluding remarks.

2. Literature review

This section briefly reviews related theoretical as well as empirical research. We should note that direct investigations into HQ separation and multi-plant operation have been limited in industrial organization, international trade, urban economics, and other related fields.

The theory of international fragmentation by Jones and Kierzkowski (2001) serves as a useful starting point. In their paper, they combine constant marginal costs of production with fixed costs for coordinating multiple production processes. These assumptions are motivated by the fact that increasing returns tend to be stronger for service activities than for production activities. If applied to our context, their model predicts that when a firm grows above the threshold size, it chooses multi-plant operations or separated HQs because it becomes profitable even after incurring fixed costs (service link costs) for linking multiple plants and operating separated HQs. According to Baldwin (2008), larger-sized firms are more likely to "unbundle" production processes and corporate functions.

Another theoretical framework relevant to our paper can be found in new economic geography (NEG) literature. The standard models in NEG primarily consider the location of single-plant firms. However, in a rare study in a two-region setting, Ekholm and Forslid (2001) analyze firms producing in both regions ("horizontal multi-region firms"), which should have multiple plants in different locations, and firms producing in low-wage regions and located away from the HQ ("vertical multi-region firms"), which should have HQs separated from the plants. The NEG model by Fujita and Thisse (2006) also examines how the decision to separate the HQ is influenced by the cost of communication between the HQ and plants, while Saito (2015) analyzes how multi-plant operations differ between high-productivity firms and low-productivity firms. While these theoretical models have focused on the impacts of trade/communication costs, this paper empirically studies not only the distance from core but also heterogeneous plant characteristics, such as plant size.[1]

Our plant-level estimation complements previous empirical research at the firm level, such as Davis and Henderson (2008) and Strauss-Kahn and Vives (2009). From U.S. firm-level data, Atalay, Hortaçsu and Syverson (2014) find that transactions of goods between upstream and downstream plants within the firm boundary are extremely rare and plant/firm size is the strongest determinant for vertical ownership. They propose that the provision of corporate intangible inputs from the HQ, rather than intra-firm trade in goods, determines which plants are

1 Our analysis also differs from recent international trade models for offshoring, as they focus on the boundary of the firm under incomplete contract (e.g., Antràs and Helpman, 2004).

owned by vertically linked firms.

On the other hand, Aarland et al. (2007) investigate the decision to separate the HQs in U.S. firms and find that firms with separated HQs tend to be larger. By relating the HQ location with such a decision, Ono (2003) argues that U.S. plants tend to rely more on HQs in outsourcing (i.e., outsourcing directly through plants less actively) when HQs are located in larger markets, where outsourcing opportunities are abundant.

Recent studies based on U.S. plant-level data analyze the impact of HQ-plant communications on the plant's performance, though they do not examine the HQ separation decision itself. Giroud (2013) finds that new airline routes that reduce HQ-plant travel time raise investment and productivity of the plants. Kalnins and Lafontaine (2013) report that plants with shorter distance to HQ tend to survive longer among business establishments in Texas.

Compared to studies on HQ separation, empirical studies on multi-plant operation have been fewer in number.[2] As far as we know, the book *The Economics of Multi-Plant Operations* by Scherer et al. (1975) is the most prominent work dedicated to the analysis of this issue. However, their study, based on the structure-conduct-performance paradigm in traditional industrial organization, focuses not on the decision of multi-plant operation per se, but on aggregate data on the number of plants or the average plant size operated only by leading firms; thus, it neglects plants/firms without a dominant market share or the effect of plant size.

Although the choice of multi-plant operation itself is *not* the focus of their analyses, several studies recently investigate how multi-plant firms differ from single-plant firms. For example, Bernard and Jensen (2007) find that multi-plant firms and U.S. multinationals are more likely to close plants in the U.S. In analyzing characteristics of closed plants, Kneller et al.

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2 Fujita and Gokan (2005) theoretically analyze whether the HQ manages one or two plants in a two-region NEG setting as in Fujita and Thisse (2006), and show that the option of multi-plant operations is chosen when trade costs are high.

(2012) confirm that domestic multi-plant firms and multinational multi-plant firms in Japan are similar.[3] Both studies suggest that multi-plant operation, not multi-nationality, is the key factor, but mainly examine whether multinationals are different from domestic firms in the particular decision: plant closure. This paper characterizes plants operated by multi-plant firms in comparison with those operated by single-plant firms, irrespective of the nationality. While foreign ownership plays an important role in our current society, the investigation of multinationals is beyond the scope of this paper due to the data limitation as explained below.[4]

Though HQ separation and multi-plant operation have been examined individually in previous literature, the same set of economic factors, such as plant size and economic geography, are quite likely to affect both decisions. Consequently, this paper investigates these two issues using the same plant-level data.

3. Plant-level data

This section describes the data used in our study. We derive plant-level panel data from Japan's *Annual Survey of Manufacturers (Kogyo Tokei* in Japanese). Our sample consists of all plants with four or more employees, as original plant-level micro-data files of the central government are maintained only for plants above this threshold size (even for the most recent census).

Data on basic plant characteristics, such as output (sales), employment (number of regular workers), and expenditure on materials, are available for all plants in the census. The census also captures valuable information regarding whether each plant is a part of a multi-plant firm.[5]

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3 Although they use detailed firm-level data, Kneller et al. (2012) concentrate on large- or medium sized firms (basically with 50 or more employees) in Japan.
4 By focusing on an early sample (1978-1990), Okubo and Tomiura (2011) avoids problems associated with relocations across national borders, as manufacturing census does not cover plants domiciled overseas. However, plant identifier to construct panel data are unavailable for these earlier years.
5 Transactions between plants operated by the same firm cannot be distinguished in the census data, but Atalay et al. (2014) report that such intra-firm transactions are limited in the U.S.

Our panel regressions introduced in the next section control for the firm-specific fixed effect, as plants owned by different firms may vary in their decision on multi-plant operation.

The census also captures data on HQ separation. Like manufacturing censuses in many other countries, Japan's *Annual Survey of Manufacturers* identifies plants by their manufacturing sites.[6] While the address of the separated HQ is not available, the census asks each plant whether its HQ is physically collocated with or separated from the plant.[7] This paper exploits this rich plant-level data to explore plant characteristics relevant to the decisions of HQ separation. We must note here that the census asks the question on HQ separation only to a plant operated by a single-plant firm, not to a plant operated by a multi-plant firm.

This paper presents estimation results from plant-level panel data covering 1992-2008.[8] We use identifiers for plants to link plants in different years for constructing panel data, identifiers for firms to link plants under the same ownership, and converters adjusting changes across years, prepared and disclosed by Japan's Research Institute of Economy, Trade and Industry (RIETI).[9] The longitudinal format of data enables us to examine switches across different plant types over years and thus helps us discuss causality.

4. Empirical results on HQ separation

4.1. Empirical specification

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6 Even if the HQ and plants are located in separate buildings, they are considered to be "collocated" as long as the plots/spaces on which they are located are covered under the same ownership or rental contract.

7 Non-production offices are not captured by the manufacturing census. Aarland et al. (2007) and Henderson and Ono (2008) use the U.S. data on "auxiliary establishments," which are non-production offices providing services to other plants/offices of the firm.

8 All plants, without any size threshold, are covered in "census years" (year with 0, 3, 5, or 8 as its last digit), but microdata on plants below the cut-off size are not maintained even in the original data-files of the government. Okubo and Tomiura (2011) report estimation results of the same model for the census years (1978, 1980, 1983, 1985, 1988, and 1990) and confirm that main results in this paper are robust.

9 To construct our dataset, we use "the Establishment Master Database" and "Firm Master Database," both provided by RIETI, as well as the converter disclosed by Abe et al.(2012).

This section estimates whether and how plant-level characteristics are related to the decision to separate HQs. We consider the following binary response model:

$$P(y=1|x)=P(y^{*}>0|x). \qquad (1)$$

The vector of explanatory variables is summarized by *x*. The binary variable *y* takes the value one (HQ located separately from the plant)[10] if the latent variable y^*, given below in (2), is positive, and zero otherwise.

$$y^{*}_{irjt}=\alpha+x_{1i}\beta_1+x_{2r}\beta_2+\eta_r+\theta_j+\lambda_t+u_{irjt} \qquad (2)$$

The plant is indexed by *i*, while the suffix *r*, *j*, and *t* denote the location (prefecture), the industry of the plant, and the year of observation, respectively. The region, industry and year fixed-effects are represented by η, θ and λ, respectively. The vector *x* in (1) is decomposed into two vectors in (2): plant characteristics (x_1), and regional characteristics (x_2). The error term *u* is a continuously distributed variable independent of *x*. We must note that this reduced-form specification (2) does not imply the direction of causality. As a robustness check, we also estimate the linear probability model with the latent variable y^* in (2) replaced by the binary variable *y* to control for plant-specific fixed effect in panel format.[11]

We concentrate on single-plant firms in estimating (2), since the census distinguishes HQ separation only among the plants operated as the single plant of the firm.[12] This focus in the census questionnaire is natural because the decision by multi-plant firms to separate HQs is inevitably influenced by other plants under the same ownership.[13]

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10 Aarland et al. (2007) analyze the firm's decision of having independent central administrative offices and the decision of locating them in the same county as the firm's production plants, by estimating two probit models separately.

11 Plant-specific effects cannot be controlled for as fixed effects in probit/logit model for plants without any organizational change during the sample period.

12 The census asks each plant to choose from the following three options: (1) a single plant collocated with HQ, (2) a single plant separated from HQ, and (3) one of multiple plants. As a result of this questionnaire design, we have no information on HQ separation among multi-plant firms.

13 Henderson and Ono (2008) concentrate on "the event where firms establish a single stand-alone

Included on the right-hand side of (2) within the vector of plant-level characteristics x_1 are the following variables associated with returns to scale in production or in management: (a) plant size in terms of employment, *SIZE* (the number of regular workers); (b) the per-worker wage (total wage payment divided by employment), *WAGE*; (c) the total factor productivity, *TFP*; and (d) the material intensity (expenditures on materials[14] divided by the output shipment value) *MAT*. We estimate *TFP* by the method of Olley and Pakes (1996) for plants of which the data on capital are available.[15]

We focus on *SIZE* because management burden is assumed to increase with employment size. For firms that have plants with many workers, decreasing returns to scale in management or the need for diverse corporate services such as accounting and legal services by large plants act as incentives to establish independent HQs. As a related finding, Atalay et al. (2014) conclude that vertically-linked plants are characterized by plant/firm size. As indicated by Strauss-Kahn and Vives (2009), HQs are also likely to be separated from production plants to give more autonomy to the managers of large plants.

On the other hand, plants with a larger number of workers might require more management attention and the local presence of plant managers, necessitating the collocation of HQs with such plants. This paper empirically investigates which of these opposing effects of plant size exerts a stronger influence on the decision to separate HQs.

Since no data disaggregated by occupations or educational attainment are available in the manufacturing census, the plant's average wage acts as a proxy for human capital. Plants with

HQ for the first time" (p.437) in their sample of multi-plant firms. On the other hand, Aarland et al. (2007) exclude single-plant firms from their analysis of HQ collocation.

14 This includes expenditures on materials, fuel, and electricity.

15 The value added is measured by the shipment minus expenditures on materials. As expenses on energy or electricity are not distinguished from material expenditures in our plant data, we cannot estimate TFP by the Levinsohn-Petrin method. Plants with less than thirty employees are dropped from the TFP estimation since their capital data are not collected by the statistics. However, Okubo and Tomiura (2011) confirmed that our main results, especially the relation with plant size, are robust for all the plants, including those without capital data, by using labor productivity.

richer human capital are expected to be given autonomy.

Productivity is included because firms improve their plant productivity by providing corporate services from their independently located HQs. Inputs from the HQs (often invisible and intangible inputs, such as brand name recognition or R&D) contribute to plant productivity. With regard to corporate intangibles, Atalay et al. (2014) find that the transactions of goods within vertically linked U.S. firms are extremely inactive, and argue that intangible inputs provided by HQs are important. In other words, strong corporate HQs are necessary for the effective management of production plants in geographically separated locations. We should not therefore presume that the direction of causality runs from plant characteristics to HQ locations.

HQ services provided to separated plants have been formalized theoretically (Ekholm and Forslid, 2001; Fujita and Gokan, 2005; Fujita and Thisse, 2006). While these models focus on communication costs between distant regions, firms may differ in expenses on communications even in the same location. Some firms are skillful in transforming information into codes suitable for distant communications or in effectively monitoring the efforts of plant managers from a distance. Productive firms are likely to excel in this regard, as suggested by previous research on the link between productivity and investment in information and communication technologies (ICT).[16] In this sense, plant productivity can also alternatively be interpreted as a (inverse) proxy for plant-specific communication costs.

This paper also investigates whether plants that purchase more materials tend to be managed by separated HQs. Management burden tends to increase with intensive use of materials, as larger expenses on materials often involve active outsourcing across firm

16 For example, Corrado and Hulten (2010) report that the contribution of communication-related expenses, not only on hardware ICT equipment but also software, marketing and branding, to productivity growth substantially increased in the U.S. during almost the same sample period as ours. Fukao et al. (2009) estimate it in the Japanese case, though they find that the impact of intangible capital was smaller than that in the U.S.

boundaries. As accumulated studies on supply chains have shown, the procurement of materials often requires well-designed management, beyond merely placing orders and expediting, such as maintaining rapid information sharing system or even involving key suppliers early in the development stage, in order to reduce time and costs spent on purchasing, and to respond to uncertainties in prices or supply disruptions.[17] As the values at stake become higher, HQs are required to become more independent, allowing them to negotiate and conclude contracts more effectively.[18] Purchasing of materials thus involves these costly management efforts.

To examine the effect of spatial organization on corporate organization (HQ separation) of production, we include as x_2 in (2) the following three region-specific variables: (a) the distance from the plant's location to the core regions, *DIST*, (b) the local industrial specialization, *LOCAL*, and (c) the urbanization of the region, *URBAN*.

DIST is measured by the minimum distance from the plant location to Tokyo or Osaka, the largest prefecture (in terms of population as well as GDP) in East and West Japan, respectively. For plants located within Tokyo or Osaka, we measure internal distance using the equation proposed by Redding and Venables (2004): $DIST = 2/3 \cdot \sqrt{Area/\pi}$, where *Area* refers to the area of Tokyo/Osaka measured in square kilometers.[19]

Firms may have incentives to separate their corporate HQ from production plants if plants are located in peripheral regions distanced from the core. Although our plant-level dataset does

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17 As indicated by the title of Cooper et al. (1997), supply chain management is "more than a new name for logistics." Lambert and Cooper (2000) summarize how various wide management considerations are required for successful supply chain management, including procurement of materials.

18 Management burden of material purchases may vary depending on the characteristics of purchased materials. For example, it should be especially harder to manage purchasing of delicately differentiated inputs or wider varieties of materials. Within our manufacturing census data, however, all available on material purchase is the total expense without any disaggregation by material types/varieties.

19 This approximation is based on the average distance between two points in a circular region. The ratio of a circumference of a circle to its diameter is expressed by "π."

not contain information on HQ locations, many HQs are in core regions. According to Matsuura (2015), around one-third of Japanese firms with central administrative offices concentrate in Tokyo, and if we combine three major metropolitan areas in Japan, the core regions attract about half of them at 2000.[20] In a related study, Duranton and Puga (2005) theoretically formalize functional specialization of regions: HQ and business services cluster in larger cities and plants cluster in smaller cities.[21] Defever (2006) reports that HQ location has a negative effect on locations of production plants in Europe, suggesting that HQs tend to locate far from plants.[22] Many firms locate their HQs in the core since HQs of other firms agglomerate and business support services are abundantly available. On the other hand, high costs of land and labor make core locations unattractive for manufacturing activities. In other words, plants located near the core are likely to function not only as manufacturing sites but also as corporate HQs. In the census's category, they are plants operated as the single plant collocated with HQ. As the investigation of such issues is intertwined with functions performed by HQs (e.g. monitoring, control, business support services, outsourcing), we admit that the lack of HQ location data make our analysis inevitably indirect and suggestive. We also interact distance with *SIZE*, as effects of the distance from the core might be alleviated by the functions of internal resources.

The other two geography variables we include in the regressions, *LOCAL* and *URBAN*, are defined as follows. First, *LOCAL* is a measure of cross-regional variations in industrial specialization based on the following Krugman index

$$LOCAL_{rt} \equiv \sum_{j} \left| s_{jrt} - s_{jt} \right| \qquad (3)$$

20 Firm-level data analyses by Matsuura (2015) are based on a different Japanese statistics concentrating on medium- or large-sized firms.

21 Rossi-Hansberg et al. (2009) theoretically show that firms decide to locate the HQ at the center and plants at the edge within a city.

22 Defever (2006) finds that production plants owned by non-European multinationals tend to collocate with R&D centers in Europe. Based on the same European data, Defever (2012) discovers co-location of production plants owned by the same multinationals in neighboring regions and in adjacent countries.

where s_{jrt} denotes the employment share of industry j in prefecture r at year t. The share of industry j in Japan's total manufacturing employment at year t is expressed by s_{jt}. This index takes the value of zero when the region's industrial structure exactly coincides with the national average. Firms are more likely to distribute plants in regions with a higher *LOCAL* index to exploit specialization gains, but less likely to separate HQ in such regions specialized in narrow range of local industries where outsourcing opportunities and corporate service availability tend to be limited.

As a measure of diversity, we define *URBAN* by the following entropy index

$$URBAN_{rt} \equiv -\sum_{j} s_{jrt} \log_2 s_{jrt} \ . \quad (4)$$

A region with high entropy has more diversified composition of industries. This urbanization index considers the region as a whole, while the former Krugman's index focuses on how the region deviates from the average in its industrial composition. HQs are expected to be separated from plants located in regions with a higher urbanization index, as various corporate services are abundantly available in urban areas compared with rural industrial concentrations. From U.S. data, Ono (2003) observes that plants are less likely to engage directly in outsourcing when their HQs are located in larger markets, indicating more important roles of HQs located in cores, where searching, matching, and contracting is easier.

Summary statistics from plant-level data are presented in Table 1. Plants are divided into three groups. The plants operated by multi-plant firms are, on average, larger than are single plants with separated HQs, which, in turn, are larger than single plants with collocated HQs. This ordering appears consistent with our perception of the firm's growth process, and consistent with the established results. All the other plant characteristics (the average wage, the productivity, and the material intensity) follow the same pecking order as the size.

Before reporting our regression results, a brief geographic description of our sample will be informative. By aggregating plant-level data to the prefecture level, Figure 1 shows how the main variables in our analysis are related with the distance from core *DIST*.[23] Plants in regions closer to core tend to be smaller and to employ higher-wage workers, as expected from high land price, high labor costs, and rich accumulation of human capital in urban core. Multi-plant operation tends to be active in remote regions. The relation with HQ separation appears unclear, disturbed by a couple of regions surrounding core but with frequent HQ separation. In the next section, we report regression results with various controls at the plant level.

4.2. Estimation results

This section reports the estimation results and discusses their implications. First four columns of Table 2 show estimates from the probit model, while the last two columns present OLS estimates from the linear probability model as a robustness check.[24] All the continuous plant-level variables are in logarithms, after adding the value one. Reported after coefficient estimates are z-statistics in probit and t-statistics in OLS. Fixed effects are controlled for prefecture, sector and year in corresponding columns in this table, while the last two columns control for plant-specific fixed effect. These controls certainly contribute to alleviating potential econometric problems associated with omitted variables. The notable findings are as follows.

First, plant size is strongly related to HQ separation. Firms tend to separate the HQ from the production plants when the plant size is large.[25] This finding is linked to the existence of certain forms of decreasing returns to scale in plant operations, such as increase in management

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[23] Among 47 prefectures in Japan, Okinawa, an isolated island prefecture, is omitted from all the graphs except that on wage.

[24] We have confirmed that our main results are robust with logit estimates.

[25] We confirm, in Okubo and Tomiura (2011), the robustness by replacing *SIZE* with the logarithm deviation from the 4-digit industry mean. This definition stems from the argument that the threshold size for HQ separation should differ depending on the production technology in each industry, possibly reflecting the minimum efficient scale.

burdens owing to an increase in the number of workers. While a larger number of workers at a plant may necessitate HQ collocation, our estimation result shows that this effect is actually dominated. Our finding regarding the positive effect of plant size is also in line with the previously reported results from U.S. firms.[26]

Although the impact of plant size is statistically significant at any conventional significance level in any specification in Table 2, we must note that the impact is not large in magnitude. A ten-percent expansion of the number of workers results in the increase in probability of HQ separation merely by 0.2% in the OLS case, as shown in the last two columns of this table, and 0.4 to 0.5% in the probit case evaluated at the mean (marginal effects omitted for brevity from the table on coefficient estimates). Marginal effects of other variables are mostly even smaller.

Second, productivity is also an important determinant of HQ location. Plants with higher productivity are significantly more likely to have their HQ separated from the production units, as theoretically predicted. We furthermore find that the per-worker wage level, a proxy for human capital, is also significant.

Third, the intensity of material use is also positively associated with HQ separation. In line with the first finding, this result is consistent with the view that management burdens are likely to increase with purchases of material inputs.

Finally, plants located far from agglomerated cores are likely to have separated HQ. This effect of distance appears somewhat attenuated in larger plants, as indicated by the negative coefficient on the interactive term *DIST*SIZE*. We also note that the negative coefficient on

[26] Aarland et al. (2007) report that firms with separated HQs are substantially bigger than those without. Strauss-Kahn and Vives (2009) argue that "small headquarters may locate close to their plants" (p.178) while discussing their finding that larger HQs are more likely to relocate. Atalay et al. (2014) also find that firm size is strongly related to the firm's choice of owning vertically linked multiple plants.

localization, but the comparison of results in different columns in the table indicates that the effects of these geography variables, especially urbanization, are not statistically significant if we control for plant fixed effect.

5. Empirical results on multi-plant operation

5.1. Empirical specification

This section investigates how plant-level characteristics are related to multiple-plant operation. We apply (1) and (2) similarly to this issue and consider the following reduced form:

$$\begin{aligned} z^*_{ifrjt} = {} & \delta_0 + \delta_1 \ln SIZE_i + \delta_2 \ln WAGE_i + \delta_3 \ln TFP_i + \delta_4 \ln MAT_i \\ & + \delta_5 \ln DIST_r + \delta_6 \ln DIST_r * SIZE_i + \delta_7 LOCAL_r + \delta_8 URBAN_r \; . \\ & + \pi_r + \phi_j + \eta_f + \mu_t + v_{ifrjt} \end{aligned} \tag{5}$$

On the left-hand side of (5) is the latent variable z^* that underlies the choice of multi-plant operation. The binary variable z takes the value one (the plant operated as part of a multiple-plant operation) if z^* is positive, and zero (single plant of the firm) otherwise. As in (2), the plant is indexed by i. The region, year, industry of the plant, and the firm operating the plant are denoted by r, t, j, and f, with the fixed effects for prefectures, sectors, years, and firms denoted by π, μ, ϕ, and η, respectively. The error term v is assumed to have a standard normal distribution. As in the HQ separation analysis, we check the robustness by estimating the linear probability model with firm-specific fixed effect. The parameters to be estimated are expressed by δ.[27] All plants (including those operated by multi-plant firms as well as those operated by single-plant firms irrespective of HQ separation/collocation) are included in the estimation of (5).[28]

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27 As in HQ regressions, we add the value one before taking logarithm to the variables except localization and urbanization.

28 As a robustness check, we estimate the same model over the sample excluding single-plant firms with collocated HQs, but we confirm that the contrast between plants operated by multi-plant firms

The regression (5) includes the same explanatory variables as in (2). The expectations on the effect of each plant variable are as follows. If management burdens increase more than proportionally with employment size, firms should have incentives to split their production across multiple plants. Due to this decreasing returns to scale, a plant operated as a part of multi-plant production should be more productive. A firm with higher productivity also has a stronger incentive to operate multiple plants due to its profitability high enough to cover fixed costs for establishing new plants, as theoretically discussed by NEG models such as Saito (2015). Plants with more skilled workers (high-wage workers) often employ production technology with economies of scale realized by concentrated production. Plants actively purchasing materials might be likely to be a part of multi-plant operation for trading these materials within a firm. The above arguments are merely a suggestion of possible interpretations, not presented as a rejection of other hypotheses. Bernard and Jensen (2007) confirm that these plant variables well characterize plants operated by multi-plant firms.[29]

However, the geography effects have not been examined in previous research of multi-plant firms, such as Bernard and Jensen (2007). The locations of plants operated by multi-plant firms (possibly with differentiated product lines or large-scale production of commodities) should be geographically dispersed, with at least some of them in the periphery, to serve the respective local markets. Single-plant firms are likely to locate their single production facility (possibly specializing in a niche market product) near the large market (core) to save transport costs.[30] The distance is interacted with size, since smaller plants are more sensitive to

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and single-plants firms with separated HQs is almost the same as in the entire sample. The estimation results are available upon request.

29 In their U.S. sample, plants operated by multi-plant firms are larger in employment size, more capital-intensive, paying higher wage, and with higher TFP than single-plant firms. They claim that “the theoretical possibilities are ambiguous” but “empirical results are quite clear” (Bernard and Jensen 2007; p.194).

30 Saito (2015) and Okubo et al. (2010) theoretically find that it is possible for single-plant firms to relocate from core to periphery when transport costs decline in a two-region world with asymmetric

the external business environment.

5.2. Estimation results

The estimation results are shown in Table 3. Essentially, all the plant characteristics share the same relation with the decision of conducting multi-plant operations as they do with the decision to separate HQs, as reported previously.[31] Large-sized, productive plants with rich human capital or with high intensity of material use tend to be operated by multi-plant firms.[32] This finding is in line with the following observation by Scherer et al. (1975): "running a multi-plant production network efficiently requires a more effective management information and control system" (p.387).[33] These plant characteristics of multi-plant firms also coincide with those discovered by Bernard and Jensen (2007) in U.S. data.

Plants located far from the cores are significantly more likely to be operated as a part of multi-plant operation. The negative coefficient on the interactive term *DIST*SIZE* shows that the drawbacks of distance from cores are partly alleviated by the internal resources in large plants. As Scherer et al. (1975) note, intra-firm factors responding to market imperfection are critical for firms that operate multiple plants. We note, however, that the statistical significance of this distance effect is noticeably lost if we control for firm-specific fixed effect in Columns 5 and 6 of Table 3. Multi-plant operation tends to be active in local industrial concentrations, but no stable or significant effect of urbanization is detected.

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market size if their productivity is low due to intensified competition against high-productivity firms in the core.

31 As in HQ separation, main variables have statistically significant impacts on the choice of multi-plant operation, but their marginal effects are small in magnitude, either in probit or in logit.

32 As in HQ separation, Okubo and Tomiura (2011) confirm that our principal findings remain robust even if we redefine the size by the deviation from the industry's mean.

33 Foster et al. (2012) find that the demand levels of plants in multi-plant firms are higher than those in single-unit plants because of the differences in brand capital, according to evidence from U.S. manufacturing census. Our observed productivity might partly be affected by such demand level differences.

6. Dynamic changes of plants

While previous two sections present estimation results on the static plant status (separation of HQ or multi-plant operation), this section examines the following two dynamic issues: entry of new plants and switches of plant types. As non-negligible number of plants change their status during our sample period, the investigation of such dynamics is important to check the robustness of our results from panel but static regressions. As the use of panel data enables us to investigate how changes in corporate organizations influence the firm's performance, we will also report results from firm-level regressions of productivity growth in the final sub-section.

6.1. Entry of new plants

This sub-section discusses new entry of plants. We pick up incumbent multi-plant firms and estimate which plants add new plants in the next period.[34] While the next section will examine which plant turns from a single plant of the firm into multi-plant operation, this section investigates which multiple plants further add newly opened plants.

Table 4 presents logit estimation results on incumbent multiple plants. The dependent variable is the binary dummy taking the value of one when the plant has a newly opened plant under the multi-plant operation by the same firm in the next year and zero otherwise. Plants large in size, with rich human capital, high productivity or intensive use of materials tend to have a newly added plant in the next period. These plants tend to distribute far from core but the distance effect is somewhat diluted in larger plants. As these findings are consistent with our previous results from static regressions, we confirm that our main results are robust even after

[34] We have also picked up newly opened plants and estimated whether they differ from other multiple plants. Our estimation results from linear probability model with firm-specific fixed effect show that new entrants tend to be small, unproductive, paying low wage, or using few materials. These plant characteristics are in line with our prior on growth path of plants.

expanding our scope to addition of new plants by multi-plant firms.

6.2. Switches of plant types

This sub-section examines dynamic switches of plant types; i.e. a plant collocated with HQ switching to a plant separated with HQ or a single plant of the firm switching to one of the multiple plants of the firm. We also consider reverse switches: a plant previously separated from HQ turning into a plant collocated with HQ or a plant operated as a part of multiple plants turning into a single plant of the firm. The analyses of these dynamic switching patterns complement previous static results, and help us discuss the causality direction.

Table 5 displays estimation results with the plant type switch as the dependent variable in the logit model.[35] The switching pattern in each column is shown in the top row of this table. The first two columns show the HQ separation/collocation change among single plants, while the last columns display the switch between single plants and multiple plants. Several points are noteworthy. All variables on the right-hand side of the regressions are in the previous year.

As the most important finding, larger plants collocated with HQ are significantly more likely to switch to plants with separated HQ. Larger single plants also tend to become a part of the firm's multi-plant operation. Small-sized plants tend to follow transitions in the reverse direction. Estimates in Table 5 also show that a single plant intensively purchasing materials tends to separate HQ or to become a part of multiple plants of the firm in the next period. We similarly find the effect of productivity. As these results from dynamic switches are consistent with our previous regressions on static plant types, we can confirm that these plant characteristics (the plant size in terms of employment, material use intensity, and productivity) are strong predictors of plant status even if we consider switches of plant types over years.

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35 We have also estimated the linear probability model to include firm-specific fixed effect, but the OLS estimates are largely similar for main coefficients.

On the other hand, the impacts of other variables appear not to be stably strong or not to perfectly coincide with previous static results. Based on this observation, we should be cautious in discussing the effects of these variables, especially economic geography factors surrounding each plant.[36]

6.3. Productivity growth at the firm level

In this final sub-section, we examine the impact of changes in corporate organization on the firm's productivity. Such analysis is made possible with firm-level data in panel format. Table 6 presents the firm-level regression results. The dependent variable is the firm's TFP growth rate. On the right-hand side of the regression, we introduce four dummy variables capturing the following organizational changes: separating HQ from the plant, collocating HQ with the plant, opening a new plant, and closing an existing plant.[37] To control for the firm's characteristics, we include *SIZE, WAGE, MAT* and distance. Fixed effects are also added for sectors as well as years.[38]

All the four columns in Table 6 show that the productivity growth is significantly high when the firm changes its corporate organization, by switching the HQ-plant collocation/separation pattern or changing the number of plants the firm operates. As the owner or CEO of a firm is supposed to reorganize in order to improve performance of the firm, our results suggest that reorganizations appear successful at least for productivity enhancement in

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36 The impact of distance is negative in all columns of Table 5, suggesting relatively active reorganizations (in both directions) at plants located proximate to core. This might at least partly reflect competitive pressures from higher costs of land and labor in core. While the sign reported in this table is not in line with our previous static results in Tables 2 and 3, we must note that Table 5 focuses on dynamic switches of plant status.

37 The number of firms covered by each regression varies, as the first/second column in Table 6 concentrates on firms with HQ previously collocated with/separated from the plant, respectively. The third and fourth columns of the table cover all plants, irrespective of the number of plants in the previous period.

38 The firm's distance from core is calculated by averaging distances over plants. The firm's sector is identified by the product with the highest share in outputs of plants.

our sample.[39] Our results on TFP growth are robust after controlling for plant characteristics and distance, but we must note that our regressions are silent on the exact mechanism how reorganizations raise TFP. As the left-hand side of the regression is the TFP growth at the year of organizational change compared with the previous year, the regressions reported here measure the instantaneous impact of reorganization, not its long-run impact. Furthermore, we cannot completely exclude the possibility that rapidly growing firms are actively reorganizing.[40] Hence, we should be cautious in deriving normative policy implications solely from these estimates.

On other variables, we find that small firms, firms with low-wage employees, firms actively purchasing materials, or firms located closer to the core tend to record high productivity *growth* (not absolute level). The effect of distance is attenuated in large-sized firms, as found in previous sections.

7. Concluding remarks

This paper has empirically investigated how plant-level characteristics are related to HQ separation and multiple-plant operation. Our estimations have shown that large-sized plants tend to be operated as a part of multi-plant operations or as the firm's single plant with separated HQs. These plant-level findings are consistent with previous firm-level results. A plant located far from the core regions is likely to be separated from HQ if it is the single plant of the firm, or to be a part of multi-plant operation. Corporate organization inside the firm and location

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39 The significantly positive impact of reorganizations is detected not only on the productivity growth but also on the growth of firm size in terms of employment. The regression results of employment growth are available upon request.

40 Although right-hand side variables are one-year lagged in these regressions, we still cannot deny the simultaneity problem. However, as almost all of our variables are supposed to be simultaneously determined, and as no other relevant plant-level data are available in the manufacturing census, it is practically impossible to find instrumental variables within our dataset.

decisions of firms are among the vital issues for current Japanese industrial policy, as the intensified global competition pressurizes many Japanese firms to re-organize and re-locate. Our findings of small but significant effects will be informative in identifying how plants differ by HQ separation or by multi-plant operation. The effects of localization or urbanization, however, turn out to be not robust enough, suggesting the difficulty of discussing geography determinants on corporate organization within plant-level data from manufacturing census.

While we have detected previously unexplored relationships with plant-level factors, several issues remain unaddressed. For example, one fruitful research avenue is linking similar plant-level data with recent new economic geography models, including Saito (2015) as an example of theoretical analysis of multi-plant operation and relocation decisions by firms with heterogeneous productivities. Tight integration of plant-level data with firm-level data will be also important, particularly for discussing outsourcing across boundaries of firms. Expanding our scope to multinationals and to overseas locations will another important goal for future research.

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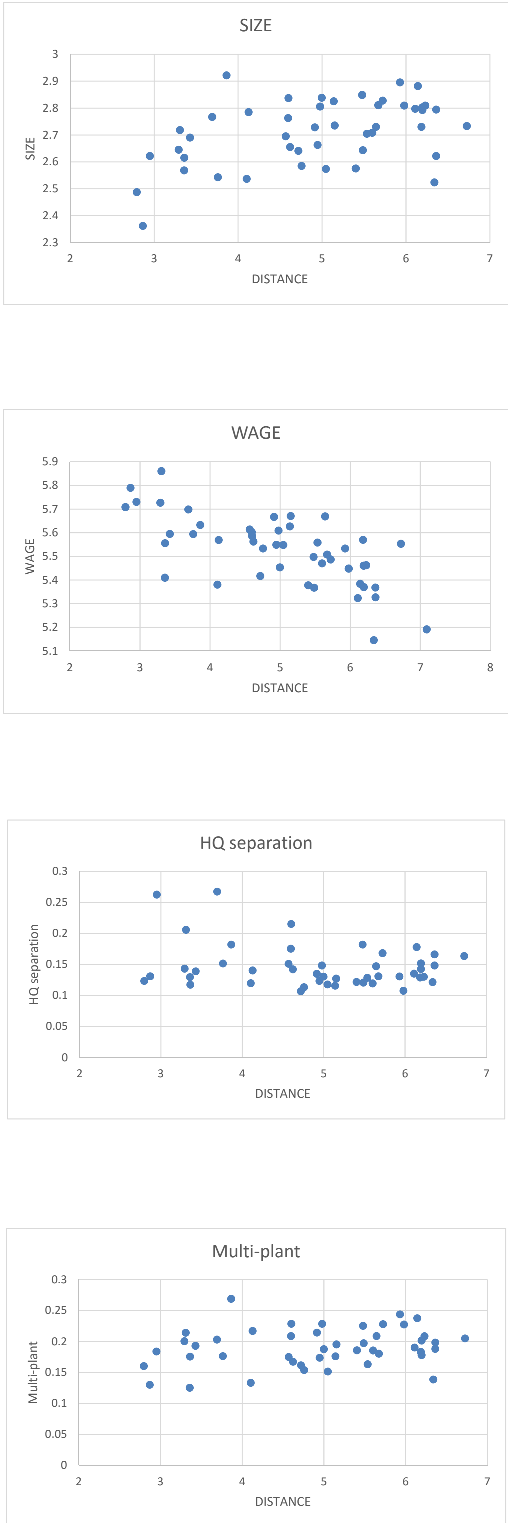
Figure 1: Relation with distance from core



(Notes) A dot represents each prefecture. See text for definitions of the variables.

Table 1: Basic Statistics

Plant types			Size	Wage	TFP	Mat	Dist	Dist*Size	Local	Urban
Single/Multiple plants	HQ separation									
SP(single-plant firm)	Collocated HQ	mean	2.384565	5.556538	5.687093	0.374109	4.258535	10.25925	9.631458	12.45412
		min	0	-3.04452	0.003575	-0.04119	2.795177	0	0	9.587886
		max	8.623833	9.547003	11.94021	120.3654	7.092491	57.84767	12.6156	13.77328
		std	0.770823	0.649038	0.770948	0.251205	1.237639	4.853275	1.124566	0.8208407
		observation	4,012,480	3,983,172	2,759,514	4,008,670	4,012,480	4,012,480	4,012,480	4,012,480
SP(single-plant firm)	Separated HQ	mean	2.719586	5.777295	6.020723	0.411621	4.204199	11.54703	9.618453	12.4966
		min	0	-1.60944	0.001836	0	2.795177	0	0	9.587886
		max	8.598773	9.276128	13.72541	935	7.092491	47.78487	12.6156	13.77328
		std	0.886379	0.517503	0.865358	1.198687	1.222236	5.398075	1.122931	0.7717046
		observation	650,720	650,278	451,535	649,150	650,720	650,720	650,720	650,720
MP(multiple-plant firm)		mean	3.419878	5.864547	6.240773	0.424804	4.358121	14.95679	9.614078	12.4318
		min	0	-3.13549	0.000223	0	2.795177	0	0	9.587886
		max	9.967214	12.76187	14.93914	1037.519	7.092491	55.33823	12.6156	13.77328
		std	1.189693	0.505046	0.929656	1.376833	1.230691	6.845737	1.147716	0.7894397
		observation	953,060	952,675	752,756	950,448	953,060	953,060	953,060	953,060
total	total	mean	2.599071	5.634765	5.830246	0.387042	4.269139	11.20561	9.627002	12.45525
		min	0	-3.13549	0.000223	-0.04119	2.795177	0	0	9.587886
		max	9.967214	12.76187	14.93914	1037.519	7.092491	57.84767	12.6156	13.77328
		std	0.951102	0.625124	0.84476	0.730146	1.23546	5.585532	1.128362	0.8102003
		observation	5,616,260	5,586,125	3,963,805	5,608,268	5,616,260	5,616,260	5,616,260	5,616,260

Table 2: HQ Separation

	1			2			3			4			5			6		
SIZE	0.2037243	217.3	***	0.1983767	171.5	***	0.2479603	69.32	***	0.2470531	69	***	0.0175001	7.31	***	0.0176234	7.33	***
WAGE	0.263083	172.8	***	0.1626035	70.48	***	0.1236676	53.19	***	0.1215987	52.19	***	0.0017666	4.22	***	0.0017939	4.28	***
TFP				0.1212866	74.77	***	0.1435627	87.16	***	0.1443595	87.6	***	0.0019084	5.5	***	0.0019592	5.64	***
MAT							0.300691	68.12	***	0.3014633	68.27	***	0.0055852	4.79	***	0.0057105	4.89	***
DIST							0.0128525	5.71	***	0.0173552	7.27	***	0.640237	619.16	***	0.6392158	598	***
DIST*SIZE							−0.010935	−13.97	***	−0.010596	−13.53	***	−0.002796	−5.46	***	−0.002788	−5.43	***
localization										−0.031493	−20.88	***				−0.001901	−4.03	***
urbanization										0.0422085	20.22	***				−8.67E−05	−0.03	
Prefecture fixed effect	Yes			Yes			No			No			No			No		
Sector fixed effects	Yes			Yes			Yes			Yes			No			No		
Year fixed effects	Yes			Yes			Yes			Yes			Yes			Yes		
Plant fixed effects	No			No			No			No			Yes			Yes		
Observations	4633450			3187721			3187721			3187721			3187721			3187721		
LR	209568.31			161428.97			133391.31			133918.73								
R−sq	0.0558			0.0621			0.0513			0.0515			0.8702			0.8446		

coefficient estimates followed by z−statistics in probit, and t−statistics in OLS
* significant at 10% level; ** significant at 5% level; *** significant at 1% level

Table 3: Multi-plant Choice

	1			2			3			4			5			6		
SIZE	0.5099258	684.37	***	0.4953102	550.59	***	0.6203986	219.42	***	0.6226472	220.18	***	0.0189994	12.02	***	0.0189022	11.95	***
WAGE	0.2451682	164.53	***	0.0710717	33.26	***	0.027724	12.78	***	0.026176	12.05	***	0.0036292	7.66	***	0.0035111	7.41	***
TFP				0.1646611	120.21	***	0.1901192	136.3	***	0.1897576	136.01	***	0.0010095	2.78	**	0.0008642	2.37	**
MAT							0.3631446	93.32	***	0.3629961	93.28	***	0.0043917	3.39	***	0.0040751	3.15	***
DIST							0.1134812	56.63	***	0.1264562	59.72	***	-0.001002	-0.6		0.0009889	0.57	
DIST*SIZE							-0.029451	-47.76	***	-0.029881	-48.47	***	-0.000843	-2.48	**	-0.000915	-2.69	**
localization										0.0292748	22.06	***				0.0084483	17.74	***
urbanization										-0.001529	-0.83					-0.00492	-4.05	***
Prefecture fixed effect	Yes			Yes			No			No			No			No		
Sector fixed effects	Yes			Yes			Yes			Yes			No			No		
Year fixed effects	Yes			Yes			Yes			Yes			Yes			Yes		
Firm fixed effects	No			No			No			No			Yes			Yes		
Observations	5,586,125			3,940,190			3,940,190			3,940,190			3,850,395			3,850,395		
LR	860331.66			709947.15			712571.79			713301.64								
R-sq	0.1686			0.1848			0.1854			0.1856			0.7792			0.8108		

coefficient estimates followed by z-statistics in probit, and t-statistics in OLS
* significant at 10% level; ** significant at 5% level; *** significant at 1% level

Table 4: New Plant Creation

Logit

SIZE	0.802898	31.7 ***
WAGE	0.304159	9.16 ***
TFP	0.290118	20.21 ***
MAT	1.035779	19.97 ***
DIST	0.41713	16.15 ***
DIST*SIZE	−0.06388	−11.62 ***
localization	−0.14035	−9.13 ***
urbanization	0.117391	5.06 ***

Observations	595864
LR	15072.24
Pseudo R−sq	0.1346
Sample	MP(multiple−plant firm)

coefficient estimates followed by z−statistics
* significant at 10% level; ** significant at 5% level; *** significant at 1% level

Table 5: Switches of Firm Types

Logit

	From Col HQ to Sep HQ		From Sep HQ to Col HQ		From SP to MP		From MP to SP	
SIZE	0.153909	5.8 ***	−0.25486	−9.33 ***	0.503415	33.61 ***	−0.81531	−46.79 ***
WAGE	0.109832	6.84 ***	−0.24632	−16.48 ***	−0.09083	−7.68 ***	−0.26207	−21.18 ***
TFP	0.131194	10.61 ***	−0.10611	−11.01 ***	0.198073	23.58 ***	−0.18242	−25.68 ***
MAT	0.247466	7.97 ***	−0.27675	−9.66 ***	0.324983	14.83 ***	−0.38553	−17.79 ***
DIST	−0.04597	−2.66 ***	−0.04357	−2.4 ***	−0.03972	−3.43 ***	−0.34544	−25.76 ***
DIST*SIZE	−0.02557	−4.24 ***	−0.02036	−3.25 ***	−0.0104	−3.1 ***	0.063781	16.27 ***
localization	−0.01518	−1.46	0.059473	5.75 ***	0.077634	10.47 ***	0.031766	4.15 ***
urbanization	0.036794	2.59 **	−0.02595	−1.78 *	0.002873	0.28	0.006006	0.56
Sector fixed effects	yes		yes		yes		yes	
Year fixed effects	yes		yes		yes		yes	
Observations	2441741		401913		2529165		615190	
LR	1978.36		6306.6		15381.29		34142.42	
Pseudo R−sq	0.0067		0.0291		0.0301		0.0913	
Sample (firm type)	Col HQ		Sep HQ		SP		MP	

NB: SP indicates single−plant firm. MP indicates multiple−plant firm.
NB: "Sep HQ" indicates separated HQ while "Col HQ" is collocated HQ.

coefficient estimates followed by z−statistics
* significant at 10% level; ** significant at 5% level; *** significant at 1% level

Table 6: Firm's TFP Growth

	1			2			3			4		
Separating HQ	0.095872	15.46	***									
Collocating HQ				0.071815	4.23	***						
Opening a plant							0.084414	15.04	***			
Closing a plant										0.078882	14.57	***
SIZE	−0.10592	−40.79	***	−0.13503	−17.3	***	−0.10944	−44.47	***	−0.10943	−44.47	***
WAGE	−0.65888	−544.4	***	−0.7492	−166.9	***	−0.66857	−572.3	***	−0.66858	−572.26	***
MAT	0.472267	158.15	***	0.553874	60.82	***	0.479178	168.61	***	0.479177	168.61	***
DIST	−0.07441	−48.46	***	−0.10668	−20.74	***	−0.07697	−52.23	***	−0.07697	−52.23	***
DIST*SIZE	0.013798	24.33	***	0.018235	10.38	***	0.014174	26.29	***	0.014171	26.28	***
Sector fixed effects	Yes			Yes			Yes			Yes		
Year fixed effects	Yes			Yes			Yes			Yes		
Observations	1,720,595			217,670			1,938,265			1,938,265		
F	16253.13			1473.78			17908.08			17907.32		
R-sq	0.2079			0.1732			0.2049			0.2049		

coefficient estimates followed by t-statistics

* significant at 10% level; ** significant at 5% level; *** significant at 1% level