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Channels of firm expansion and contraction*

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Abstract

We propose a model of firm expansion and contraction choices which integrates approaches from the industrial organization and corporate finance literature within one unified setting. Firms respond to shocks to their marginal costs by expanding or contracting output via internal or external adjustment. External adjustment can take place via greenfield investment or disinvestment and/or mergers and acquisitions (M&As). We show theoretically how the choice of adjustment strategy varies systematically with observable characteristics, in particular firm size and the magnitude of adjustment. We then test the model's predictions using novel business register data for the United Kingdom. In contrast to existing datasets, our data allow for a joint analysis of all three adjustment forms highlighted by the theory. The data are also not limited to publicly traded firms and cover almost the entire universe of UK firms, representing 99% of UK employment and turnover. We find broad support for the theoretical predictions of our model.

Keywords: Adjustment Channels, Mergers and Acquisitions, Greenfield Investment, Investment

JEL classification: E22, G31, G32, G33, L25

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1 Introduction

Firms constantly adapt to changes in their market environment and technological possibilities. One key mechanism through which this adjustment takes place is given by changes in the scale and scope of their operations. Indeed, the importance and magnitude of micro-level adjustments in employment and turnover has been extensively documented in the literature (e.g., Davis et al., 2006; Maksimovic and Phillips, 2001; Foster et al., 2008; Hsieh and Klenow, 2009).

Changes to firm-level employment and turnover can be achieved through three principal channels. Firstly, firms can adjust internally, i.e., by changing employment or output at existing production facilities while continuing to use them. Secondly, firms can expand or contract externally by changing the number of establishments or divisions they operate. This external adjustment in turn can happen via greenfield investment, i.e., by shutting down or opening up establishments or divisions, or by using the market for corporate control, i.e., by buying or selling parts of their operations through mergers and acquisitions (M&As).

The choice of adjustment channel can have very different economic implications. Firm and plant closures usually lead to substantial social costs in terms of temporary unemployment of workers or lost technological and product-specific know-how (e.g., Jovanovic and Rousseau, 2008). Alternatively, researchers like Jensen (1993) have argued that M&As present a more efficient form of resource transfer between expanding and contracting firms and that over-restrictive regulations prevent firms from using this mechanism.

Despite these considerations, there exists to our knowledge no analysis of the different adjustment channels in one integrated setting. Research in corporate finance has analysed determinants of M&As and asset sales without comparing them to other adjustment mechanisms such as plant contraction or closure (e.g., Maksimovic and Phillips, 2001). Likewise, studies in industrial economics have been predominantly at the establishment level and have thus implicitly abstracted from M&A adjustment (e.g., Disney et al., 2003). This is an important omission, not only because of the different economic implications described above, but also because the choice of adjustment channel depends on the alternatives available to the individual firm.

In this paper, we aim to fill this gap by analysing all three adjustment channels in a unified framework. Based on recent developments in the literature on multi-product firms (e.g., Nocke and Yeaple, 2008), we model the firm problem of choosing the preferred adjustment channel in response to shocks to the marginal costs of production. Specifically, individual firms' decisions between internal and external adjustment are driven by a span of control problem which gives rise to a trade-off between firm scope and efficiency at existing establishments. On the other hand, the preferred mode of external adjustment is determined on the market for corporate control (M&A), where potential acquirers are matched with potential targets, both of which face the outside option of remaining unmatched and relying on greenfield adjustment instead.

We show that larger firms and firms undertaking larger expansions and contractions systematically rely on external adjustment strategies (i.e., greenfield or M&As). Among the firms using external adjustment channels, larger firms use more greenfield investment relative to M&As for expansions, but not for contractions. Firms undertaking larger adjustments predominantly do so via M&As rather than via greenfield investment.

We test the model’s predictions using unique business register data for the United Kingdom. In contrast to most of the existing literature, our data allow for an analysis of all three adjustment channels in one integrated setting. They are also not limited to publicly traded firms or to the manufacturing sector, and as such are much more comprehensive than existing sources, representing over 99% of UK turnover and employment.

Using these data, we show that all three adjustment channels are quantitatively important and that firms trade off their usage in patterns consistent with our theoretical predictions. While less than 3% of adjustments take place through the creation or closure of new establishments or the use of M&As, these events trigger changes in employment and turnover which are up to 40 times larger than the average internal adjustment (i.e., changes at existing establishments). Large adjustments are thus primarily undertaken via external channels. Firm size is also an important predictor for the choice of adjustment channel, with large firms being considerably more likely to rely on external adjustment forms than smaller firms. Our model also correctly predicts that among the external adjustment forms, greenfield expansions are predominantly undertaken by the largest firms, and that large expansions mostly proceed via M&As.

The rest of the paper is structured as follows. Section 2 describes our model and derives the theoretical predictions. Section 3 describes our data in more detail and Section 4 presents basic descriptive statistics on the use of adjustment forms by UK firms. Section 5 uses formal econometric analysis to test our model’s predictions, and Section 6 concludes.

2 The Model

We consider an economy where monopolistically competitive firms differ in their organizational capabilities. Firms can comprise multiple plants, and we assume that a given firm’s plants sell products which are differentiated from one another. Key to the firm problem is a trade-off between scope and productivity, similar to Nocke and Yeaple (2008), Eckel and Neary (2010) and Bernard, Redding and Schott (2009, 2010).

Our model’s basic structure follows Nocke and Yeaple (2008). There is a mass L of identical consumers with the following linear-quadratic utility function:

$$U = \int x(j)dj - \int [x(j)]^2 dj - 2\sigma \left[\int x(j)dj \right]^2 + Z, \quad (1)$$

where $x(j)$ is consumption of product j in the differentiated goods industry, Z is consumption of an outside good, and $\sigma > 0$ is a parameter that measures the degree of product differentiation. Assuming consumer income is sufficiently large, an individual consumer’s inverse demand for product j is then given by

$$p(j) = 1 - 2x(j) - 4\sigma \int x(l)dl. \quad (2)$$

The outside good is produced in a perfectly competitive industry which operates under constant returns to scale. In the differentiated goods industry, there is a mass M of atomless firms which differ in their *organizational capabilities*. A firm’s organizational capability is given by the pair (c_0, θ) , where both c_0 and θ are positive parameters drawn from continuous distribution

functions defined over a finite support. Firms can comprise any number $n \geq 1$ of plants, all of which operate under the common organizational capabilities idiosyncratic to the firm. Hence, there is (technological) heterogeneity across firms, but not across the individual plants belonging to a given firm.

We presume that firms have constant marginal cost at the plant level but that they face decreasing returns to the span of control at the firm level.¹ Specifically, the marginal cost of production at the plant level is given by $c(n; c_0, \theta)$. We assume that an increase in a firm's number of plants increases its individual plants' marginal cost, $\partial c(n; c_0, \theta)/\partial n > 0$. Moreover, we assume that $\partial^2 c(n; c_0, \theta)/\partial n \partial \theta < 0$; accordingly, holding fixed the number $n > 1$ of plants, a firm's marginal cost decreases in θ , $\partial c(n; c_0, \theta)/\partial \theta < 0$. Consistent with these properties is the following specification of the marginal cost common to the plants of a firm with organizational capability (c_0, θ) :

$$c(n; c_0, \theta) = c_0 + \frac{n}{\theta}. \quad (3)$$

This specification gives marginal cost in multi-plant firms as a linear function defined by an intercept $c_0 + 1/\theta$ for a single-plant firm ($n = 1$) and a slope $1/\theta$.² For obvious reasons, we call c_0 the *autonomous marginal cost* term.

In addition to the marginal cost of production $c(n; c_0, \theta)$, a firm faces a fixed cost of ρ per plant. Each firm's profit maximization problem then consists of the choice of (i) the number of plants n , and (ii) the quantity x_j of output produced at each of its plants $j \in [1, n]$. Hence, the firm problem involves an *extensive margin* (the choice of the number of plants) as well as an *intensive margin* (the quantity choice at a given plant).

Importantly, however, a firm's adjustment along the intensive and extensive margins can proceed via different channels: Firms can adjust internally by expanding or contracting their production capacity at existing establishments. Alternatively, they can adjust externally by increasing or decreasing the number of establishments belonging to the firm; this can happen either via the creation or closure of establishments (greenfield investments/divestitures), or via the relocation of existing establishments from one firm to another (mergers and acquisitions). Our subsequent analysis will devote particular attention to firms' choice between these alternative modes of adjustment.

2.1 Equilibrium analysis

The preference structure underlying (1) and (2) gives rise to a *linear demand system*. In equilibrium, each firm operating in the differentiated goods industry then faces a linear residual demand curve for the output produced in each of its individual plants:

$$D(p) = \frac{L}{2}(a - p), \quad (4)$$

¹See Lucas (1978). In what follows, we ignore integer constraints.

²Notice the following differences to related specifications employed in the literature. Nocke and Yeaple (2008) postulate $c(n; c_0, \theta) = c_0 n^{1/\theta}$, where $1/\theta$ denotes the elasticity (rather than the slope) of marginal cost with respect to the number of plants n . Ordering plants $j \in [1, n]$, Eckel and Nary (2010) assume $c(j; c_0, \theta) = c_0 + \frac{j}{\theta}$, implying that the negative scope effect of adding another plant works only on the marginal plant (rather than on the marginal and inframarginal plants).

where p is the price and a the endogenous demand intercept, which is taken as given by the monopolistically competitive firms. It follows that inverse demand is

$$P(x) = a - \frac{2x}{L}, \quad (5)$$

where x is output.

Consider a firm with organizational capability (c_0, θ) . We investigate the firm problem in three steps. First, for a given number n of plants, we analyze the intensive margin problem, i.e., the firm's plant-level quantity choice. Then, we consider the firm's extensive margin problem, i.e., the determination of firm scope via the optimal choice of the number n of plants. Finally, we analyze the firm's extensive margin decision between greenfield expansion/contraction and activity on the market for corporate control.

2.1.1 Plant-level quantity choice

The endogenous demand intercept a is common to all firms and thus to their respective plants. Since marginal costs, as determined by (c_0, θ) , are symmetric across a firm's plants, the firm will optimally produce the same quantity at each of its plants. Given a firm's number n of plants, its profit-maximizing level of output per plant is then given by

$$x(c(n; c_0, \theta)) \equiv \arg \max_x [P(x) - c(n; c_0, \theta)] x = \frac{L}{4}(a - c(n; c_0, \theta)). \quad (6)$$

Accordingly, gross profit at the plant level is

$$\pi(c(n; c_0, \theta)) \equiv [P(x(c(n; c_0, \theta))) - c(n; c_0, \theta)] x(c(n; c_0, \theta)) = \frac{L}{8}(a - c(n; c_0, \theta))^2. \quad (7)$$

Specifically, it follows from (7) that plant-level profit is decreasing and convex in marginal cost. For future reference, we also define optimal sales per plant as

$$s(c(n; c_0, \theta)) \equiv P(x(c(n; c_0, \theta)))x(c(n; c_0, \theta)) = \frac{L}{8}(a^2 - c(n; c_0, \theta)^2). \quad (8)$$

Notice that sales per plant is an indicator for plant size.

2.1.2 Determination of firm scope

Firm scope, defined as the number n of plants of a given firm, is optimally determined as

$$n(c_0, \theta) \equiv \arg \max_n [\pi(c(n; c_0, \theta)) - \rho] n, \quad (9)$$

where $\rho \in \{r, R\}$ is an indicator for the fixed costs of adding another plant (as detailed below, r stands for the fixed cost of creating a new plant via greenfield investment, while R represents the fixed cost from M&A). We assume $r \leq R$. From the envelope theorem, $\pi'(c(n(c_0, \theta); c_0, \theta)) = -x(c(n(c_0, \theta); c_0, \theta))$, so that the first-order condition for $n(c_0, \theta)$ can be written as

$$[\pi(c(n(c_0, \theta); c_0, \theta)) - \rho] - n(c_0, \theta)x(c(n(c_0, \theta); c_0, \theta)) \frac{\partial c(n(c_0, \theta); c_0, \theta)}{\partial n} = 0. \quad (10)$$

From (10), the impact of an additional plant on the firm's profit can be decomposed into two terms: the net profit of the marginal plant, and the negative effect via the increased marginal cost of production $c(n(c_0, \theta); c_0, \theta)$ at all plants. Following Nocke and Yeaple (2008), we refer to this second term as the *inframarginal cost effect*.

The specification of marginal cost in (3) implies $n(c_0, \theta) \partial c(n(c_0, \theta); c_0, \theta) / \partial n = n(c_0, \theta) / \theta = c(n(c_0, \theta); c_0, \theta) - c_0$. Hence, the choice of the number of plants enters (10) only through the induced marginal cost $\tilde{c}(c_0, \theta) \equiv c(n(c_0, \theta); c_0, \theta)$. Adopting the assumption that the fixed cost ρ is not too large, so that the firm earns a strictly positive profit if it only operates a single plant, i.e.,

$$\pi(c_0 + 1/\theta) = [P(x(c_0 + 1/\theta)) - (c_0 + 1/\theta)] x(c_0 + 1/\theta) > \rho, \quad (11)$$

We proceed with a description of the relationship between a firm's organizational capability (c_0, θ) and its marginal cost.

Lemma 1 *The optimal determination of firm scope implies that a firm's number of plants $n(c_0, \theta)$ is chosen such that the induced marginal cost $\tilde{c}(c_0, \theta)$ is increasing in c_0 and invariant to θ . Hence, conditional on c_0 , firms with a greater organizational capability θ optimally choose a larger number $n(c_0, \theta)$ of plants.*

For a given number n of plants, the magnitude of the inframarginal cost effect exerted by the marginal plant is decreasing in θ . Thus, firms with a higher θ optimally choose a larger number of plants. Given our specification in (3), $n(c_0, \theta)$ is increasing at a rate such that induced marginal cost $\tilde{c}(c_0, \theta)$ is invariant to θ . In equilibrium, therefore, $\tilde{c}(c_0, \theta)$ is determined by the autonomous cost term c_0 , whereby a higher c_0 gives rise to higher induced marginal cost.

2.2 Implications for internal and external adjustment

Lemma 1 has important implications for the pattern of adjustment of firms in response to technology shocks.

Proposition 1 *Consider the effect of a shock to a firm's autonomous marginal cost c_0 .*

(i) *Optimal adjustment to a shock to c_0 implies*

$$\frac{d\tilde{c}(c_0, \theta)}{dc_0} > 0, \quad \frac{d^2\tilde{c}(c_0, \theta)}{dc_0^2} < 0, \quad \frac{dn(c_0, \theta)}{dc_0} < 0, \quad \frac{d^2n(c_0, \theta)}{dc_0^2} < 0.$$

Hence, induced marginal cost is increasing in c_0 but at a decreasing rate, while a firm's optimal number of plants is decreasing in c_0 at an increasing rate.

(ii) *The elasticity of induced marginal cost with respect to c_0 , $\varepsilon_{\tilde{c}(c_0, \theta)}(c_0) \equiv \frac{d\tilde{c}(c_0, \theta)}{dc_0} \frac{c_0}{\tilde{c}(c_0, \theta)}$, is positive and increasing in c_0 . Hence, a relative shock to a firm's autonomous marginal cost c_0 , $\frac{dc_0}{c_0}$, has a larger relative effect on the firm's induced marginal cost, $\frac{d\tilde{c}(c_0, \theta)}{\tilde{c}(c_0, \theta)}$, the larger its autonomous marginal cost c_0 .*

(iii) The elasticity of a firm's optimal number of plants with respect to c_0 , $\varepsilon_n(c_0) \equiv \frac{dn}{dc_0} \frac{c_0}{n}$, is negative and decreasing in c_0 . Hence, a relative shock to a firm's autonomous marginal cost c_0 , $\frac{dc_0}{c_0}$, has a smaller relative effect on the firm's optimal number of plants, $\frac{dn}{n}$, the larger its autonomous marginal cost c_0 .

Notice that the three parts of Proposition 1 are a reflection of the same basic mechanism. In response to a shock to their marginal cost, firms can adjust their number of plants in order to partially compensate the effects of the shock. In particular, as the magnitude of the underlying shock increases, the firm's optimal adjustment strategy increasingly relies on the external margin; as a consequence, the shock's impact on induced marginal cost is mitigated.

As noted above, the linear demand system implies that plant-level profit, defined in (7), is decreasing and convex in marginal cost. Hence, firms with low marginal cost face stronger incentives to exercise this channel of *external adjustment*, which helps to mitigate the impact of a given shock on induced marginal cost. Conversely, firms with high marginal cost have less external adjustment and thus more volatile marginal cost.

This property of marginal cost across firms which differ in their organizational capabilities has corresponding effects on plant-level production and sales revenue, respectively. This is the margin of *internal adjustment*. From (6), plant-level output decreases linearly in marginal cost. The linear demand system, in turn, implies that the elasticity of demand increases as output decreases; hence, from (8), sales revenue at the plant level is decreasing and concave in marginal cost. In other words, high cost firms have a higher volatility of both marginal cost and plant-level activity as measured by output and sales revenue. This means that internal adjustment, i.e., variations of the scale of production at existing plants, is more pronounced at high cost firms.

Finally, we relate firms' cost structure to directly observable characteristics. In particular, an empirical measure of firm size is given by the firm's aggregate sales across its plants

$$S(\tilde{c}(c_0, \theta)) \equiv n(c_0, \theta)s(\tilde{c}(c_0, \theta)) = n(c_0, \theta) \frac{L}{8} (a^2 - \tilde{c}(c_0, \theta)^2). \quad (12)$$

From Proposition 1, a firm's optimal number of plants is decreasing in its organizational capability c_0 and thus in its induced marginal cost. Therefore, since both the number of plants and sales per plant are decreasing in c_0 , there results an inverse relationship between c_0 and firm size, $dS(\tilde{c}(c_0, \theta))/dc_0 < 0$. Moreover, $d^2S(\tilde{c}(c_0, \theta))/dc_0^2 < 0$. On the basis of these insights, our previous findings can be restated as follows.

Corollary 1 Consider the effect of a shock to a firm's autonomous marginal cost c_0 .

- (i) Small (high c_0) firms respond with more internal adjustment than large (low c_0) firms.
- (ii) Large (low c_0) firms respond with more external adjustment than small (high c_0) firms.
- (iii) Large adjustments (high changes in $S(\tilde{c}(c_0, \theta))$) rely more (less) on the external (internal) margin of adjustment than small adjustments (small changes in $S(\tilde{c}(c_0, \theta))$).

2.3 External adjustment channels

The firm's preferred channel of external adjustment, i.e., the decision between the creation or closure of establishments (greenfield investments/divestitures) on the one hand and changes in firm scope brought about by participation in the market for corporate control (mergers and acquisitions) on the other hand, is determined such as to maximize the gains from such adjustment.

2.3.1 Valuation of plants

A given plant's assets are composed of its physical capital as well as the property rights over the output it sells, which are embodied in the fixed costs r of creating a new plant via greenfield investment. Suppose each plant has a Cobb-Douglas production function, where $\alpha < \frac{1}{2}$ is the capital share in the production costs. Then, the plant's book value is given by

$$\begin{aligned} b(\tilde{c}(c_0, \theta)) &= \alpha \tilde{c}(c_0, \theta) x(\tilde{c}(c_0, \theta)) + r \\ &= \alpha \tilde{c}(c_0, \theta) \frac{L}{4} (a - \tilde{c}(c_0, \theta)) + r, \end{aligned} \quad (13)$$

where the first term is the book value of the capital used for production, while the second term represents the fixed cost of greenfield investment. Conversely, the market value of the plant and its assets is given by

$$\begin{aligned} \tilde{m}(\tilde{c}(c_0, \theta)) &= P(x(\tilde{c}(c_0, \theta))) x(\tilde{c}(c_0, \theta)) - (1 - \alpha) \tilde{c}(c_0, \theta) x(\tilde{c}(c_0, \theta)) \\ &= [P(x(\tilde{c}(c_0, \theta))) - (1 - \alpha) \tilde{c}(c_0, \theta)] x(\tilde{c}(c_0, \theta)) \\ &= \frac{1}{2} [a - (1 - 2\alpha) \tilde{c}(c_0, \theta)] \frac{L}{4} (a - \tilde{c}(c_0, \theta)), \end{aligned} \quad (14)$$

where the first term is revenue from sales, while the second term corrects for the incurred labor costs. It is also convenient to define the capacity-adjusted market value of a plant

$$\begin{aligned} m(\tilde{c}(c_0, \theta)) &= \frac{\tilde{m}(\tilde{c}(c_0, \theta))}{x(\tilde{c}(c_0, \theta))} = [P(x(\tilde{c}(c_0, \theta))) - (1 - \alpha) \tilde{c}(c_0, \theta)] \\ &= \frac{1}{2} [a - (1 - 2\alpha) \tilde{c}(c_0, \theta)], \end{aligned} \quad (15)$$

which gives the market value of the plant's assets per unit of output $x(\tilde{c}(c_0, \theta))$.

2.3.2 Capital conversion

Heterogeneity in firms' organizational capabilities gives rise to differences in marginal costs across firms. Let \tilde{c}^i denote the induced marginal costs common to all plants in firm i , and consider two heterogenous firms whose plants have marginal costs of \tilde{c}^l and \tilde{c}^h , $\tilde{c}^l < \tilde{c}^h$, respectively. The market for corporate control relocates capital from high cost firms (targets) to low cost firms (acquirers).³ We assume that the acquirer incurs fixed costs $R \geq r$ from an acquisition.

³This is the basic take of the 'Q-theory of mergers' (Jovanovic and Rousseau, 2002).

In addition, there are costs $\Gamma(\tilde{c}^l, \tilde{c}^h)$ of converting high cost capital into low cost capital.⁴ We make the following assumption.

Assumption 1 *The conversion costs $\Gamma(\tilde{c}^l, \tilde{c}^h)$ satisfy the following properties:*

- (i) $\Gamma(\tilde{c}^l, \tilde{c}^h)$ is proportional to $m(\tilde{c}^l)x(\tilde{c}^h)$, the market value of a low cost plant producing at the capacity of a high cost plant;
- (ii) controlling for $m(\tilde{c}^l)x(\tilde{c}^h)$, $\Gamma(\tilde{c}^l, \tilde{c}^h)$ is increasing and convex in the difference of marginal costs, $(\tilde{c}^h - \tilde{c}^l)$.

Our assumptions on $\Gamma(\tilde{c}^l, \tilde{c}^h)$ have a number intuitive implications. Part (i) captures an opportunity cost effect: As the endogenous demand intercept a increases, the costs of converting high cost capital into low cost capital increase; accordingly, the costs of a merger are procyclical.⁵ Notice also that the proportionality assumption allows the interpretation of $\Gamma(\tilde{c}^l, \tilde{c}^h)/x(\tilde{c}^h)$ as the conversion costs per unit of capacity transacted. We also make use of the proportionality property to write

$$\Gamma(\tilde{c}^l, \tilde{c}^h) = \gamma(\tilde{c}^l, \tilde{c}^h)m(\tilde{c}^l)x(\tilde{c}^h).$$

Part (ii) reflects the fact that production technologies are not perfectly mobile across firms; in particular, the larger the technological gap between the acquirer and the target, the higher the cost of converting inferior capital into more productive capital.

2.3.3 The market for corporate control

Our previous analysis in Section 2.2 implies that, depending on the idiosyncratic cost shock a firm receives, it may either want to keep its number of plants constant (no external adjustment) or alternatively adjust the firm's scope by means of external adjustment. The latter firms which seek to adjust externally, in turn, can do so by increasing or decreasing the number of their plants. Accordingly, since the model's structure implies that a firm can never find it optimal to simultaneously act as a buyer and a seller, the market for corporate control involves two disjoint set of agents: potential acquirers and potential targets.⁶

Potential participants in the takeover market have always the option to stay out. Specifically, firms that want to increase their number of plants can do so via greenfield expansion, while contracting firms have the option of plant closure. Moreover, we abstract from hostile takeovers by assuming that firms can repel unwanted bids.⁷

Formally, potential acquirers and potential targets interact in a *two-sided matching game*, deciding whether and with whom to match. An equilibrium in this model is described as a *stable*

⁴For a similar assumption see Han and Rousseau (2009).

⁵Empirical evidence... cleansing effect of recessions... Heidhues et al. paper...

⁶Hence, we conceptualize mergers as 'acquisitions' rather than 'mergers of equals'. Given the difference between acquirer and target characteristics reported above, this appears justified.

⁷In their study of mergers among publicly traded U.S. firms, Andrade et al. (2001) report that between 1973 and 1998, only 8.3% of all takeover bids were hostile and only 4.4% eventually succeeded. We do not explain such mergers.

assignment, i.e., a profile of matches where (i) no matched agent would prefer to remain unmatched, and (ii) there are no two (matched or unmatched) agents who prefer to form a new alternative match.

Let \mathcal{A} denote the set of potential acquirers, and let \mathcal{T} denote the set of potential targets. Notice that both of these sets are composed of a continuum of agents. Since mergers always involve low cost firms buying plants from high cost firms, we identify a generic $\iota \in \mathcal{A}$ via \tilde{c}^l and a generic $\tau \in \mathcal{T}$ via \tilde{c}^h . In detail, we define a merger as the relocation of an individual plant from a high cost firm (\tilde{c}^h) to low cost firm (\tilde{c}^l).⁸

A necessary condition for a M&A transaction relocating capital from high cost firms (\tilde{c}^h) to low cost firms (\tilde{c}^l) to take place is that there are (gross) gains from it:

$$H(\tilde{c}^l, \tilde{c}^h) \equiv [1 - \gamma(\tilde{c}^l, \tilde{c}^h)] m(\tilde{c}^l)x(\tilde{c}^h) - R > 0.$$

However, since a low cost firm's plants produce at capacity $x(\tilde{c}^l) > x(\tilde{c}^h)$, the residual capacity must be added via internal investment; hence, the gain from obtaining a new plant of efficient scale $x(\tilde{c}^l)$ via merger (and subsequent internal investment) is

$$G(\tilde{c}^l, \tilde{c}^h) = [1 - \gamma(\tilde{c}^l, \tilde{c}^h)] m(\tilde{c}^l)x(\tilde{c}^h) - R + [m(\tilde{c}^l) - \alpha\tilde{c}^l] [x(\tilde{c}^l) - x(\tilde{c}^h)]. \quad (16)$$

Similar to (16), we define the relevant outside options for the parties in the market for corporate control. For a potential acquirer, the payoff from remaining unmatched on the merger market and expanding by greenfield investment at scale $x(\tilde{c}^l)$ is

$$G(\tilde{c}^l, 0) = m(\tilde{c}^l)x(\tilde{c}^l) - [\alpha\tilde{c}^l x(\tilde{c}^l) + r] = [m(\tilde{c}^l) - \alpha\tilde{c}^l] x(\tilde{c}^l) - r = \frac{L}{8}(a - \tilde{c}^l)^2 - r.$$

For a potential target, the payoff from remaining unmatched on the merger market and contracting via the sale of disembodied used capital is

$$G(0, \tilde{c}^h) = \lambda\alpha\tilde{c}^h x(\tilde{c}^h) = \lambda\alpha\tilde{c}^h \frac{L}{4}(a - \tilde{c}^h),$$

where $\lambda \leq 1$ is a factor scaling the salvage value from disassembling existing capital via plant closure.⁹ The (net) surplus created by a merger is then defined as $\Delta(\tilde{c}^l, \tilde{c}^h) \equiv G(\tilde{c}^l, \tilde{c}^h) - G(\tilde{c}^l, 0) - G(0, \tilde{c}^h)$, where

$$\begin{aligned} \Delta(\tilde{c}^l, \tilde{c}^h) &= [1 - \gamma(\tilde{c}^l, \tilde{c}^h)] m(\tilde{c}^l)x(\tilde{c}^h) - R + [m(\tilde{c}^l) - \alpha\tilde{c}^l] [x(\tilde{c}^l) - x(\tilde{c}^h)] \\ &\quad - [m(\tilde{c}^l) - \alpha\tilde{c}^l] x(\tilde{c}^l) + r - \lambda\alpha\tilde{c}^h x(\tilde{c}^h) \\ &= \{-\gamma(\tilde{c}^l, \tilde{c}^h)m(\tilde{c}^l) + \alpha\tilde{c}^l - \lambda\alpha\tilde{c}^h\} x(\tilde{c}^h) - (R - r). \end{aligned} \quad (17)$$

A first insight relates to the case of $\Gamma(\tilde{c}^l, \tilde{c}^h) = 0$, i.e., an environment where there are no conversion costs. In this case, it is straightforward to show that the effects of a potential

⁸Maksimovic and Phillips (2001) show that more than half of all mergers and acquisitions in the U.S. involve trade in individual plants and divisions rather than entire corporations. Explain that subsequent analysis considers plants (rather than firms) as the relevant units... one-to-one matching...

⁹Jovanovic and Rousseau (2002), Warusawitharana (2008).

acquirer's and a potential target's marginal cost, respectively, on the (gross) gains from a merger are

$$\frac{\partial G(\tilde{c}^l, \tilde{c}^h)}{\partial \tilde{c}^l} \Big|_{\Gamma=0} < 0, \quad \frac{\partial G(\tilde{c}^l, \tilde{c}^h)}{\partial \tilde{c}^h} \Big|_{\Gamma=0} < 0.$$

The first partial derivative is negative because, given \tilde{c}^h , an increase in \tilde{c}^l implies that the efficiency gains realized as a consequence of a takeover are lower. That the second partial derivative is negative reflects the fact that the increased efficiency gains per unit of capacity transacted in a takeover are overcompensated by foregone gains due to the reduced volume of the transaction itself. Finally, for $\Gamma(\tilde{c}^l, \tilde{c}^h) = 0$, the cross-derivative is

$$\frac{\partial^2 G(\tilde{c}^l, \tilde{c}^h)}{\partial \tilde{c}^l \partial \tilde{c}^h} \Big|_{\Gamma=0} = \frac{\partial^2 G(\tilde{c}^l, \tilde{c}^h)}{\partial \tilde{c}^h \partial \tilde{c}^l} \Big|_{\Gamma=0} < 0.$$

This has an important implication (Roth and Sotomayor, 1990).

Lemma 2 *Absent conversion costs, i.e., for $\Gamma(\tilde{c}^l, \tilde{c}^h) = 0$, the function $G(\tilde{c}^l, \tilde{c}^h)$ is submodular, and any stable assignment on the merger market involves negative assortative matching.*

However, the presence of conversion costs may twist this result. Intuitively, the fact that $\Gamma(\tilde{c}^l, \tilde{c}^h)$ is increasing and convex in the difference $(\tilde{c}^h - \tilde{c}^l)$ punishes potential matches between technologically distant partners, i.e., mergers that would otherwise generate the highest (gross) gains. We therefore have:

Lemma 3 *Under sufficiently large conversion costs $\Gamma(\tilde{c}^l, \tilde{c}^h)$, the function $G(\tilde{c}^l, \tilde{c}^h)$ is supermodular, and any stable assignment on the merger market involves positive assortative matching.*

Appendix A.5 provides an explicit condition ensuring supermodularity of $G(\tilde{c}^l, \tilde{c}^h)$.

In what follows, we assume that the conversion costs are not too large; accordingly, the equilibrium assignment profile will be negatively assortative. Then, the following pattern of outcomes obtains.

1. Expansions of relatively large firms: Under negative assortative matching, low cost acquirers take over high cost targets. However, at the same time, the conversion costs imply that matches between technologically too distant partners are not viable. It follows that very large firms that seek to expand externally, i.e., very low cost potential acquirers, are unlikely to be matched profitably. In addition, the small transaction size when taking over a high cost target prevents large, low cost firms from incurring the fixed cost differential $(R - r) \geq 0$ associated with a takeover. Hence, ceteris paribus, large firms are more likely to expand via greenfield investment instead.
2. Contractions of relatively small firms: For the same reasons also very small firms that seek to contract externally, i.e., very high cost potential targets, are unlikely to be matched profitably. Hence, ceteris paribus, small firms are more likely to contract via plant closure instead.

3. Expansions of relatively small firms: Irrespective of the matching pattern, mergers always relocate capital from high cost to low cost firms. Since the assignment is negatively assortative, this means that relatively small expanding firms are matched to relatively large (but smaller than the acquirer) targets. Hence, the cost differential and thus the incurred conversion costs are relatively mild. Moreover, the transaction will be relatively large and therefore justify incurring the fixed cost differential $(R - r) \geq 0$. Hence, ceteris paribus, small firms are more likely to expand via M&A.
4. Contractions of relatively large firms: For the same reasons also relatively large firms that seek to contract externally, i.e., low cost potential targets, are more likely to be matched profitably. Hence, ceteris paribus, large firms are more likely to contract via M&A.
5. Transaction size: In line with the previous arguments, large transactions are more likely to proceed via M&A rather than via greenfield (dis)investment.

Similar to Corollary 1, these implications can be assessed empirically. Before doing so, we first turn to a description of the micro-data underlying the empirical part of our paper.

3 Data Description

Our primary data source is the Business Structure Database (BSD) which is maintained by the Office for National Statistics in the United Kingdom. The BSD is constructed from annual snapshots of the UK’s business register, the IDBR. For each year between 1997 and 2005, it contains the universe of British companies which were either registered for Value Added Tax (VAT) purposes or operated a Pay as You Earn (PAYE) income tax scheme. In 2005 the BSD was comprised of 2.2 million live enterprises, representing an estimated 99 per cent of economic activity in terms of employment and turnover (ONS, 2006). The comprehensiveness of the BSD is in contrast to the data sources used in related studies of M&A activity which focus mainly on publicly traded, and thus large, firms (e.g., Jovanovic and Rousseau, 2002; Warusawitharana, 2008).

The BSD captures the structure of ownership of firms, plants and business sites that make up the British economy using three aggregation categories: the enterprise, enterprise group and local unit. According to the official definition (ONS, 2006), an enterprise “is the smallest combination of legal units that is an organisational unit producing goods or services, which benefits from a certain degree of autonomy in decision-making, especially for the allocation of its current resources”. An enterprise group is “an association of enterprises bound together by legal and/or financial links”. Finally, a local unit is “an enterprise or part thereof (e.g., a workshop, factory, warehouse or office) situated in a geographically identified place”.

Upon entry into the IDBR, each local unit, enterprise and enterprise group is allocated a unique reference number which remains with the unit for as long as it stays on the register. Furthermore, the ONS maintains a list of local units for each enterprise and combines enterprises to form enterprise groups by using information from Dun and Bradstreet, supplemented by the VAT system (ONS, 2006). Thus, every local unit also has an enterprise reference and every enterprise an enterprise group reference number.

Taken together, these identifiers allow the analysis of demographic events over time. We developed an algorithm to identify these events, following a general typology provided by Eurostat (European Commission, 2003). In our methodology, the most basic event is a change in employment or turnover at a continuing enterprise (“internal adjustment”). This is easily observed from the entries of two adjacent years for the same enterprise. If an enterprise identifier disappears from the data, we code this as a firm exit. Likewise, the appearance of a new identifier is coded as a firm entry (“greenfield investment”). Finally, the combination of enterprise and enterprise group references allows for the analysis of ownership changes. For example, if enterprise group A buys enterprise 1 from enterprise group B, the enterprise reference number of enterprise 1 would remain unchanged but its enterprise group identifier would change from A to B. Of course, an enterprise group can carry out several or all of these activities in a given year. For example, it might expand employment and turnover at one of its existing enterprises, create a new enterprise via greenfield investment and buy another one from another enterprise group (“M&A investment”).

This methodology can be implemented at different levels of aggregation. In this paper, we take the enterprise group as the decision-making unit and analyse how it changes turnover and employment through adjustments at its existing enterprises and the acquisition/sale or creation/closure of new ones.¹⁰ A priori, we would expect the choice of aggregation level not to matter very much since the three levels coincide for the majority of firms. For example, over 80 per cent of enterprises have exactly one local unit and the average number of local units per enterprise is 1.7. Likewise, the average number of enterprises per enterprise group is 1.07.

4 Descriptive Statistics

In line with our theoretical model and also with existing work (e.g., Jovanovic and Rousseau, 2002; Warusawitharana, 2008), we focus on continuing firms, i.e. firms which existed in the current period, will not exit in their entirety in the next period, and which change employment or turnover between periods.

We start our analysis by exploring what fraction of gross expansions and contractions take place through internal adjustment, greenfield investment or closures, and M&As.¹¹ Table 1 displays the fraction of all adjustments which take place through the three channels. Note that firms

¹⁰In practice, different approaches have different advantages and disadvantages. For example, the enterprise group-local unit level allows for a finer distinction between greenfield and internal investment (to take up the earlier example, it is impossible to distinguish between the creation of a new local unit within an existing enterprise and the expansion of existing local units within the same enterprise when working at the enterprise group-enterprise level). On the other hand, local unit identifiers are considered by the ONS to be less stable over time than enterprise identifiers (i.e., local units sometimes change their identifiers which creates problems of false exit in our methodology).

¹¹“Gross expansion/contraction” means that we separately account for expansions and contractions within the same enterprise group (e.g., a firm might be expanding employment at one division and closing plants in another). The overall (net) adjustment is simply the difference between gross expansion and gross contraction. In practice, the vast majority of firms either expand or contract, so that the differences between looking at gross vs. net adjustment are negligible (see table 1). We focus on gross adjustments since this is closer to most of the theoretical literature in this area in which firms either expand or contract.

can use several channels at the same time so that the percentages do not have to add up to 100%.

It is evident from table 1 that M&As and greenfield investment are rare events. On average between 1997 and 2005, these two channels were used for less than 4% of employment expansions and contractions, and for less than 2% of turnover adjustments. The vast majority of both expansion and contractions occurred via internal adjustments. Also note that for internal adjustments, adjustments of turnover are much more frequent than adjustments of employment but that the same is not true for M&As and greenfield.

Table 2 shows that, when they occur, M&A and greenfield are major events. The average M&A expansion is 15 times bigger than the average internal expansion for employment and almost 40 times bigger for sales. Likewise, the average M&A contraction is 20-30 times larger than internal contractions. Greenfield investments and disinvestments are also much bigger than internal adjustments, in particular on the firm contraction side. These descriptive statistics thus present some initial evidence for the prediction of our model that large contractions and expansions are undertaken via external adjustment channels.

Table 3 completes the picture by looking at the aggregate importance of all three channels. Despite their infrequent occurrence, the much bigger transaction sizes of external adjustments imply that greenfield investment and M&A still account for a large fraction of overall employment and turnover adjustments. Table 3 displays the exact numbers. As seen, the two forms together account for 20% to 25% of total turnover and employment expansions and for 25% to 40% of contractions. M&A generally accounts for a larger share of overall adjustments (15% of turnover and 20% of employment) and is of equal importance on the expansion and on the contraction side of adjustment. Greenfield, in contrast, is significantly more important in explaining contractions: 11% of aggregate turnover and 15% of employment reductions are achieved via firm/establishment closures while the corresponding numbers on the expansion side are at most a third of this (2% for turnover and 5% for employment).

5 Econometric Evidence

We now turn to a more formal test of our model's predictions. To summarize, these predictions are as follows:

1. Small firms rely more on internal adjustment than large firms.
2. Large expansions and contractions are predominantly undertaken via external adjustment.
3. When choosing between the two forms of external adjustment, firms rely more on M&As than on greenfield when the desired adjustment size is large.
4. When choosing between the two forms of external adjustment, large firms rely more on greenfield than M&As to expand, but rely more on M&As to contract.

To test these predictions, we employ multivariate fractional regression methods (see Mullahy, 2005; Papke and Wooldridge, 1996). Denoting the fraction of a gross expansion or contraction carried out by firm i through adjustment form m by y_{im} , we assume that:

$$E(y_{im}|x_i) = \frac{\exp(x_i\alpha_j)}{\sum_{m=1}^M \exp(x_i\alpha_j)} = \frac{\exp(x_i\alpha_j)}{1 + \sum_{m=1}^{M-1} \exp(x_i\alpha_j)} \quad (18)$$

where matrix x_i contains the independent variables (firm size, expansion size) and α_j the corresponding regression coefficients (note the normalization $\alpha_M = 0$). The advantage of the multinomial functional form embodied in (18) is that it imposes two conditions which capture key features of our data. First, $E(y_{im}|x_i) \in [0, 1]$ for all i and m ; and secondly, $\sum_{m=1}^M E(y_{im}|x_i) = 1$ for all i .

Estimation of the parameters in (18) is carried out via pseudo-maximum-likelihood methods (see Mullahy, 2005, for details). A desirable feature of the multivariate fractional logit model is that the parameters α_j will be consistently estimates even when y_{im} takes on values at the extremes of the bounded range they occupy (i.e. $y = 0$ or $y = 1$, as is frequently the case in our data). All that is required is that the conditional mean $E(y_{im}|x_i)$ is correctly specified (see Papke and Wooldridge, 1996, for the univariate case; Mullahy, 2005, provides an extension to the multivariate case analysed here).

Table 4 shows results for this baseline specification. We have chosen internal adjustment as the excluded category so that coefficient estimates should be interpreted as changes relative to internal expansions or contractions. Looking at the relative importance of external and internal adjustment first, we see that internal adjustment clearly declines as a fraction of overall adjustment as the size of the planned expansion or contraction increases. This is consistent with predictions 1 and 2 above. Also consistent with these predictions is that firms increasingly rely on greenfield and M&As for expansions as they grow in size. Larger firms also rely more on M&As than internal adjustment for contractions. The one pattern not consistent with our model is that large firms tend to use greenfield disinvestment less, not more, than internal contractions. Our intuition for this finding is that large firms are constrained in the use of establishments closures by factors outside of our model (e.g., closures of plants of major national companies are highly political events and usually opposed by the electorate and thus politicians).

Next, we turn to the comparison of the two external adjustment channels, greenfield and M&As. First, consistent with predictions 3, an increasing share of expansions is carried out via M&As than greenfield as the size of the overall expansion grows (the relevant coefficient estimate is 2-3 times as large for M&As). Contrary to the model's predictions, however, large contractions are predominantly carried out via greenfield disinvestment. Our model is again more successful for our fourth and final prediction. As our theory predicts, large firms carry out a larger share of expansions via greenfield investment, but use relatively more M&As for contractions.

As a robustness check, we carry out similar regressions using Tobit and Poisson as two more standard estimation techniques. Both are suitable for accomodating the large number of zeros for M&A and greenfield adjustment (compare table 2) but do not impose any adding-up constraints on predicted values. Reassuringly, the results shown in table 5-6 demonstrate that the qualitative findings described above carry through with these alternative estimation techniques.

In conclusion, our model is reasonably successful in replicating the broad patterns of adjustment choices in our data. Our conjecture is that the two deviations from the theoretical predictions observed in the data are due to institutional feature not presently modelled.

6 Conclusions

We presented a model of firm expansion and contraction choices which unifies existing approaches in industrial organization and corporate finance. In response to shocks to the marginal costs of production, firms choose between internal and external forms of adjustment, where the latter can take the form of greenfield investment/disinvestment or mergers and acquisitions (M&As). We showed that larger firms and firms undertaking larger expansions and contractions systematically rely on external adjustment strategies (i.e., greenfield or M&As). Among the firms using external adjustment channels, larger firms use more greenfield investment relative to M&As for expansions, but not for contractions. Firms undertaking larger adjustments predominantly do so via M&As rather than via greenfield investment.

We tested the model's predictions using unique business register data for the United Kingdom, representing 99% of UK employment and turnover. We showed that all three adjustment channels analysed in our model are quantitatively important and that firms trade off their usage in patterns consistent with our theoretical predictions.

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A Appendix

A.1 The linear demand system

See Nocke and Yeaple (2008).

A.2 Proof of Lemma 1

Since the choice of the number of plants enters (10) only through the induced marginal cost $\tilde{c}(c_0, \theta) \equiv c(n(c_0, \theta); c_0, \theta)$, the optimal determination of firm scope can equivalently be formalized in terms of choosing $\tilde{c}(c_0, \theta)$ rather than n . Hence, (10) can be rewritten as

$$\begin{aligned}\Psi(\tilde{c}(c_0, \theta)) &= [P(x(\tilde{c}(c_0, \theta))) - \tilde{c}(c_0, \theta)] x(\tilde{c}(c_0, \theta)) - \rho - (\tilde{c}(c_0, \theta) - c_0) x(\tilde{c}(c_0, \theta)) \\ &= \frac{L}{8}(a - \tilde{c}(c_0, \theta))^2 - \rho - (\tilde{c}(c_0, \theta) - c_0) \frac{L}{4}(a - \tilde{c}(c_0, \theta)) = 0.\end{aligned}\quad (19)$$

Notice that $\Psi(c_0) = \frac{L}{8}(a - c_0)^2 - \rho > \frac{L}{8}(a - (c_0 + 1/\theta))^2 - \rho > 0$, where the last inequality follows from (11). Moreover, $\Psi(a) = -\rho < 0$. Since $\Psi(c)$ is continuous, this implies that there exists a $\tilde{c}(c_0, \theta)$ such that $\Psi(\tilde{c}(c_0, \theta)) = 0$. We claim that $\tilde{c}(c_0, \theta)$ is unique. To see this, notice that $\Psi(\tilde{c}(c_0, \theta)) = 0$ and $\rho > 0$ imply $\frac{L}{8}(a - \tilde{c}(c_0, \theta))^2 - (\tilde{c}(c_0, \theta) - c_0) \frac{L}{4}(a - \tilde{c}(c_0, \theta)) > 0$ and thus

$$(a - \tilde{c}(c_0, \theta)) - 2(\tilde{c}(c_0, \theta) - c_0) > 0.\quad (20)$$

Taking the partial derivative of $\Psi(\tilde{c}(c_0, \theta))$ with respect to c yields

$$\Psi_c(\tilde{c}(c_0, \theta)) = -\frac{L}{4} [2(a - \tilde{c}(c_0, \theta)) - (\tilde{c}(c_0, \theta) - c_0)] < 0,$$

where the last inequality follows from (20). The uniqueness of $\tilde{c}(c_0, \theta)$ now follows from $\Psi_c(\tilde{c}(c_0, \theta)) < 0$.

Finally, we show that $\frac{d\tilde{c}(c_0, \theta)}{dc_0} > 0$ and $\frac{d\tilde{c}(c_0, \theta)}{d\theta} = 0$. From the implicit function theorem,

$$\frac{d\tilde{c}(c_0, \theta)}{dc_0} = -\frac{\Psi_{c_0}(\tilde{c}(c_0, \theta))}{\Psi_c(\tilde{c}(c_0, \theta))}, \quad \text{and} \quad \frac{d\tilde{c}(c_0, \theta)}{d\theta} = -\frac{\Psi_\theta(\tilde{c}(c_0, \theta))}{\Psi_c(\tilde{c}(c_0, \theta))}.$$

Since $\Psi_{c_0}(\tilde{c}(c_0, \theta)) = \frac{L}{4}(a - \tilde{c}(c_0, \theta)) > 0$, $\Psi_\theta(\tilde{c}(c_0, \theta)) = 0$ and $\Psi_c(\tilde{c}(c_0, \theta)) < 0$, it follows that $\frac{d\tilde{c}(c_0, \theta)}{dc_0} > 0$ and $\frac{d\tilde{c}(c_0, \theta)}{d\theta} = 0$.

A.3 Proof of Proposition 1

Recall (19),

$$\Psi(\tilde{c}(c_0, \theta)) = \frac{L}{8}(a - \tilde{c}(c_0, \theta))^2 - \rho - (\tilde{c}(c_0, \theta) - c_0) \frac{L}{4}(a - \tilde{c}(c_0, \theta)) = 0,$$

which can be totally differentiated to imply

$$\frac{d\tilde{c}(c_0, \theta)}{dc_0} = \frac{(a - \tilde{c}(c_0, \theta))}{[2(a - \tilde{c}(c_0, \theta)) - (\tilde{c}(c_0, \theta) - c_0)]} > 0, \quad (21)$$

where the last inequality follows from (20). Hence,

$$\frac{d^2\tilde{c}(c_0, \theta)}{dc_0^2} = \frac{-(a - \tilde{c}(c_0, \theta))}{[2(a - \tilde{c}(c_0, \theta)) - (\tilde{c}(c_0, \theta) - c_0)]^2} < 0. \quad (22)$$

Moreover, the elasticity of induced marginal cost with respect to c_0 is

$$\varepsilon_{\tilde{c}(c_0, \theta)}(c_0) \equiv \frac{d\tilde{c}(c_0, \theta)}{dc_0} \frac{c_0}{\tilde{c}(c_0, \theta)} = \frac{(a - \tilde{c}(c_0, \theta))c_0}{[2(a - \tilde{c}(c_0, \theta)) - (\tilde{c}(c_0, \theta) - c_0)] \tilde{c}(c_0, \theta)} > 0.$$

We claim that this elasticity is increasing in c_0 . To see this, notice that

$$\frac{d}{dc_0} (\varepsilon_{\tilde{c}(c_0, \theta)}(c_0)) = \frac{(a - \tilde{c}(c_0, \theta)) [2(a - \tilde{c}(c_0, \theta)) - \tilde{c}(c_0, \theta)]}{[2(a - \tilde{c}(c_0, \theta)) - (\tilde{c}(c_0, \theta) - c_0)]^2 \tilde{c}(c_0, \theta)} > 0,$$

where the last inequality follows from (20).

From the specification of marginal cost in (3), $c(n; c_0, \theta) = c_0 + \frac{n}{\theta}$, and thus

$$\frac{d\tilde{c}(c_0, \theta)}{dc_0} = \frac{dc(n; c_0, \theta)}{dc_0} = \frac{\partial c(n; c_0, \theta)}{\partial c_0} + \frac{\partial c(n; c_0, \theta)}{\partial n} \frac{dn}{dc_0}.$$

From (21), $\frac{d\tilde{c}(c_0, \theta)}{dc_0}$ is known, while (3) implies that the partial derivatives are $\frac{\partial c(n; c_0, \theta)}{\partial c_0} = 1$ and $\frac{\partial c(n; c_0, \theta)}{\partial n} = \frac{1}{\theta}$. It follows that

$$\frac{dn}{dc_0} = \theta \left(\frac{d\tilde{c}(c_0, \theta)}{dc_0} - 1 \right) = -\theta \frac{[(a - \tilde{c}(c_0, \theta)) - (\tilde{c}(c_0, \theta) - c_0)]}{[2(a - \tilde{c}(c_0, \theta)) - (\tilde{c}(c_0, \theta) - c_0)]} < 0, \quad (23)$$

where the last inequality follows from (20). Hence, from (22),

$$\frac{d^2n}{dc_0^2} = \theta \left(\frac{d^2\tilde{c}(c_0, \theta)}{dc_0^2} \right) < 0.$$

Moreover, the elasticity of n with respect to c_0 is

$$\varepsilon_n(c_0) \equiv \frac{dn}{dc_0} \frac{c_0}{n} = -\theta \frac{[(a - \tilde{c}(c_0, \theta)) - (\tilde{c}(c_0, \theta) - c_0)] c_0}{[2(a - \tilde{c}(c_0, \theta)) - (\tilde{c}(c_0, \theta) - c_0)] n} < 0.$$

We claim that this elasticity is decreasing in c_0 . To see this, notice that

$$\begin{aligned} \frac{d}{dc_0} (\varepsilon_n(c_0)) = \\ -\theta \frac{[(a - \tilde{c}(c_0, \theta)) - (\tilde{c}(c_0, \theta) - c_0)] [2(a - \tilde{c}(c_0, \theta)) - \tilde{c}(c_0, \theta)] + c_0 [2(a - \tilde{c}(c_0, \theta)) - (\tilde{c}(c_0, \theta) - c_0)]}{[2(a - \tilde{c}(c_0, \theta)) - (\tilde{c}(c_0, \theta) - c_0)]^2 n} < 0, \end{aligned}$$

where the last inequality follows from (20).

A.4 Proof of Corollary 1

From (12), firm-level sales are given by

$$S(\tilde{c}(c_0, \theta)) \equiv n(c_0, \theta)s(\tilde{c}(c_0, \theta)) = n(c_0, \theta) \frac{L}{8} (a^2 - \tilde{c}(c_0, \theta)^2).$$

Thus, we have

$$\frac{dS(\tilde{c}(c_0, \theta))}{dc_0} = \frac{dn}{dc_0} \frac{L}{8} (a^2 - \tilde{c}(c_0, \theta)^2) - n \frac{L}{8} 2\tilde{c}(c_0, \theta) \frac{d\tilde{c}(c_0, \theta)}{dc_0} < 0, \quad (24)$$

where the last inequality follows from (21) and (23). Moreover,

$$\frac{d^2S(\tilde{c}(c_0, \theta))}{dc_0^2} = \dots < 0. \quad (25)$$

The claims of Corollary 1 now follow from (24) and (25) together with the results stated in part (i) of Proposition 1.

A.5 Proof of Lemma 3

Provide condition here.

Table 1 – Choice of Adjustment Strategy (1997-2005)

| | Internal adjustment | M&A | Greenfield | All forms (#) |
|----------------------|---------------------|-------|------------|---------------|
| Employment | | | | |
| - Gross expansions | 99.11% | 1.53% | 0.60% | 1,672,516 |
| - Gross contractions | 98.38% | 1.71% | 1.12% | 1,418,009 |
| Turnover | | | | |
| - Gross expansions | 99.8% | 0.50% | 0.20% | 5,044,793 |
| - Gross contractions | 99.56% | 0.66% | 0.44% | 3,600,784 |

Source: ONS and authors' calculations.

Notes: Table shows unweighted fraction of all adjustments taking place via internal adjustment, M&As and greenfield investment or disinvestment. Figures are averages over 1997-2005. Employment is measured in numbers of employees, turnover in '000s of British pounds.

Table 2 – Average Adjustment Size by Channel

| | Internal adjustment | M&A | Greenfield investment/dis-investment | All forms (average) |
|----------------------|---------------------|---------|--------------------------------------|---------------------|
| Employment | | | | |
| - Gross expansions | 9.1 | 138.2 | 86.7 | 11.5 |
| - Gross contractions | 7.5 | 148.3 | 161.3 | 11.6 |
| Turnover | | | | |
| - Gross expansions | 882.3 | 34831.7 | 11108.2 | 1070.6 |
| - Gross contractions | 1143.4 | 34164.1 | 37325.0 | 1520.1 |

Source: ONS and authors' calculations.

Notes: Table shows unweighted fraction of all adjustments taking place via internal adjustment, M&As and greenfield investment or disinvestment. Figures are averages over 1997-2005. Employment is measured in numbers of employees, turnover in '000s of British pounds.

Table 3 – Aggregate Importance of Adjustment Forms

| | Internal adjustment | M&A | Greenfield | All forms (sum) |
|----------------------|---------------------|-------|------------|-----------------|
| Employment | | | | |
| - Gross expansions | 77.32 | 18.23 | 4.52 | 2,771,429 |
| - Gross contractions | 62.65 | 21.63 | 15.49 | 2,371,429 |
| Turnover | | | | |
| - Gross expansions | 81.77 | 16.10 | 2.01 | £776 bill. |
| - Gross contractions | 74.41 | 14.83 | 10.80 | £787 bill. |

Source: ONS and authors' calculations.

Notes: Table shows fraction of all adjustments taking place via internal adjustment, M&As and greenfield investment or disinvestment. Figures are yearly averages over 1997-2005. Employment is measured in numbers of employees, turnover in billions of British pounds.

Table 4 – Firm Size, Expansion/Contraction Size and Choice of Adjustment Form (multivariate fractional regressions)

| | Employment - Expansion | Turnover - Expansion | Employment - Contraction | Turnover - Contraction |
|-------------------------------------|------------------------|----------------------|--------------------------|------------------------|
| M&As | | | | |
| - Firm size (logs) | 0.329 (40.43) *** | 0.116 (13.74)*** | 0.486 (50.64)*** | 0.368 (32.97)*** |
| - Expansion/contraction size (logs) | 0.563 (54.31) *** | 0.707 (88.06)*** | 0.395 (32.94)*** | 0.433 (42.06)*** |
| Greenfield | | | | |
| - Firm size (logs) | 0.644 (57.16) *** | 0.454 (29.18)*** | -1.623 (-107.12)*** | -1.658 (-167.82)*** |
| - Expansion/contraction size (logs) | 0.163 (10.20) *** | 0.368 (24.78)*** | 2.684 (150.33)*** | 2.078 (223.47)*** |
| Observations | 1,616,416 | 4,407,833 | 1,524,055 | 3,697,829 |
| Industry FE | 3 digit | 3 digit | 3 digit | 3 digit |

Source: ONS and authors' calculations.

Notes: Table shows results for multinomial fractional logit regressions. Figures in brackets are t-stats clustered at the 3-digit industry-level. The dependent variables are the fractions of M&As, greenfield and internal adjustment in total employment or turnover adjustment. Internal adjustment is the excluded category. The regressors are firm size and the size of the overall expansion and contraction (both in logs). Employment is measured in numbers of employees, turnover in '000s of British pounds. +, *, and ** indicate statistical significance at the 10%, 5%, and 1%-level, respectively.

Table 5 –Firm Size, Expansion/Contraction Size and Choice of Adjustment Form (Tobit)

| | Employment | | | Turnover | | |
|---------------------|--------------------|----------------------|----------------------|---------------------|----------------------|----------------------|
| | M&A | Greenfield | Internal | M&A | Greenfield | Internal |
| Expansions | | | | | | |
| Log(firm size) | 0.238 (71.10)** | 0.355 (59.76)** | -0.009 (186.09)** | 0.120 (44.07)** | 0.237 (47.67)** | -0.003 (309.96)** |
| Log(expansion size) | 0.423 (92.70)** | 0.209 (32.40)** | -0.022 (244.82)** | 0.407 (114.38)** | 0.268 (52.46)** | -0.003 (321.52)** |
| Observations | 1616416 | 1616416 | 1616416 | 4897526 | 4897526 | 4897526 |
| Industry FE | 3 digit | 3 digit | 3 digit | 3 digit | 3 digit | 3 digit |
| Contractions | | | | | | |
| Log(firm size) | 0.414 (75.30)** | -0.390 (156.23)** | 0.062 (208.21)** | 0.300 (64.92)** | -0.563 (275.09)** | 0.036 (342.86)** |
| Log(contr. size) | 0.252 (42.41)** | 0.729 (234.90)** | -0.148 (364.58)** | 0.287 (66.99)** | 0.790 (361.71)** | -0.053 (623.87)** |
| Observations | 1536683 | 1536683 | 1536683 | 3710344 | 3710344 | 3710344 |
| Industry FE | 3 digit | 3 digit | 3 digit | 3 digit | 3 digit | 3 digit |

Source: ONS and authors' calculations.

Notes: Table shows results for Tobit regressions. Figures in brackets are t-stats based on standard errors clustered at the 3-digit industry-level. The dependent variable is the fraction of M&As, greenfield and internal adjustment in total employment or turnover adjustment. The regressors are firm size and the size of the overall expansion and contraction (both in logs). Employment is measured in numbers of employees, turnover in '000s of British pounds. +, *, and ** indicate statistical significance at the 10%, 5%, and 1%-level, respectively.

Table 6 –Firm Size, Expansion/Contraction Size and Choice of Adjustment Form (Poisson)

| | Employment | | | Turnover | | |
|---------------------|--------------------|---------------------|---------------------|--------------------|---------------------|---------------------|
| | M&A | Greenfield | Internal | M&A | Greenfield | Internal |
| Expansions | | | | | | |
| Log(firm size) | 0.282 (11.33)** | 0.606 (24.28)** | -0.010 (9.76)** | 0.074 (4.06)** | 0.425 (15.36)** | -0.003 (11.38)** |
| Log(expansion size) | 0.429 (17.24)** | 0.024 (0.91) | -0.023 (12.91)** | 0.616 (29.01)** | 0.282 (10.23)** | -0.003 (12.34)** |
| Observations | 1616416 | 1616416 | 1616416 | 4897526 | 4897526 | 4897526 |
| Industry FE | 3-digit | 3-digit | 3-digit | 3-digit | 3-digit | 3-digit |
| Contractions | | | | | | |
| Log(firm size) | 0.497 (20.73)** | -0.524 (13.93)** | 0.063 (12.33)** | 0.323 (12.94)** | -0.522 (13.79)** | 0.036 (9.25)** |
| Log(contr. size) | 0.152 (7.24)** | 0.769 (21.59)** | -0.162 (20.82)** | 0.339 (15.36)** | 0.729 (24.62)** | -0.054 (14.43)** |
| Observations | 1536683 | 1536683 | 1536683 | 3710344 | 3710344 | 3710344 |
| Industry FE | 3-digit | 3-digit | 3-digit | 3-digit | 3-digit | 3-digit |

Source: ONS and authors' calculations.

Notes: Table shows results for Poisson regressions. Figures in brackets are t-stats based on standard errors clustered at the 3-digit industry-level. The dependent variable is the fraction of M&As, greenfield and internal adjustment in total employment or turnover adjustment. The regressors are firm size and the size of the overall expansion and contraction (both in logs). Employment is measured in numbers of employees, turnover in '000s of British pounds. +, *, and ** indicate statistical significance at the 10%, 5%, and 1%-level, respectively.