Technological Specialization and the Decline of Diversified Firms

INTERNET APPENDIX

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IA.1 Proofs

Proof of Proposition 1.

First let us set, without loss of generality, $\alpha_i = 0$ and $\alpha_j < 1/2$; also recall that we are assuming $\sigma < 1/4$. It may additionally be useful to clarify the convention we are employing with respect to circle location, namely that $N_1 + x$ is equivalent to $N_2 + x$, for any two integers N_1 and N_2, and all $x \in [0, 1]$.

<u>Case 1:</u> $z \leq \sigma$

Consider the left circle in Figure IA.1. Let us denote the six adjacent regions in the following way. Starting at 0 and going clockwise until z defines region $\mathcal{R}_1$; starting at z and going clockwise until σ defines region $\mathcal{R}_2$; and so forth. The location of the project generated by i can occur in regions 1, 2, 5, or 6; the location of the project generated by j can occur in regions 1, 2, 3, or 6. Since profits are linear in distance between BUs and projects, the optimal allocation is the one that minimizes total "travel" from the (assigned) projects to each division/BU. Inspection of the different possibilities allows us to determine the optimal policy for each case, with results shown in Table IA.1.

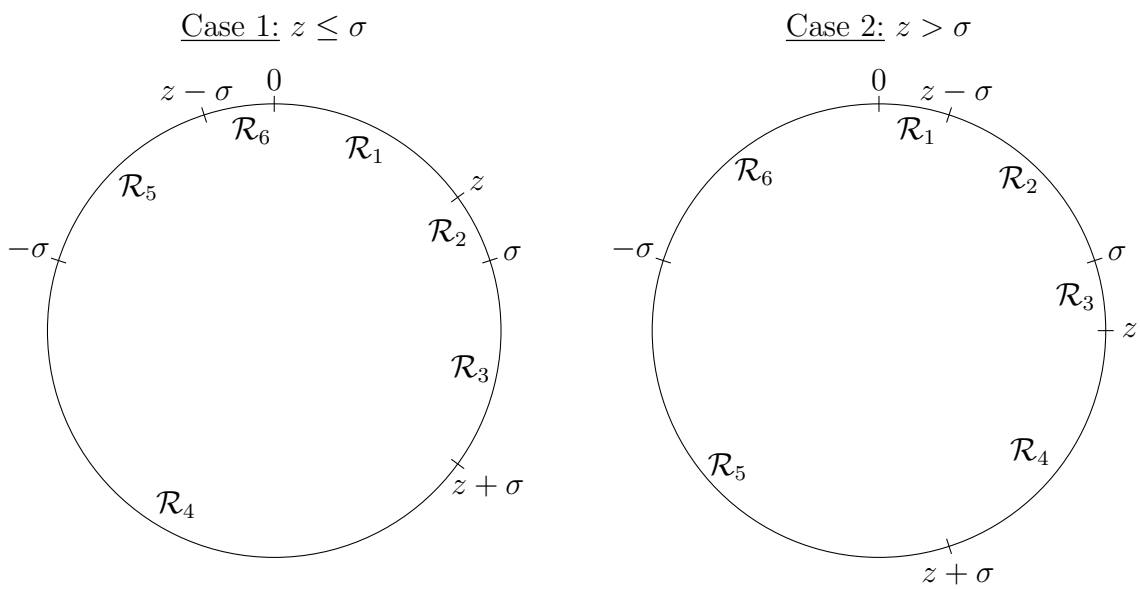

Figure IA.1: Splitting the circle into regions. In the left example, $\sigma = 0.2$ and $z = 0.15$. In the right example, $\sigma = 0.2$ and $z = 0.25$.

Location of α_{P_i}	Location of α_{P_j}	Optimal allocation policy
$\mathcal{R}_1$	$\mathcal{R}_1$	Swap if and only if $\alpha_{P_j} < \alpha_{P_i}$.
$\mathcal{R}_1$	$\mathcal{R}_2$	Never swap.
$\mathcal{R}_1$	$\mathcal{R}_3$	Never swap.
$\mathcal{R}_1$	$\mathcal{R}_6$	Always swap.
$\mathcal{R}_2$	$\mathcal{R}_1$	Always swap.
$\mathcal{R}_2$	$\mathcal{R}_2$	Indifferent (no swap assumed).
$\mathcal{R}_2$	$\mathcal{R}_3$	Indifferent (no swap assumed).
$\mathcal{R}_2$	$\mathcal{R}_6$	Always swap.
$\mathcal{R}_5$	$\mathcal{R}_1$	Never swap.
$\mathcal{R}_5$	$\mathcal{R}_2$	Never swap.
$\mathcal{R}_5$	$\mathcal{R}_3$	Never swap.
$\mathcal{R}_5$	$\mathcal{R}_6$	Indifferent (no swap assumed).
$\mathcal{R}_6$	$\mathcal{R}_1$	Never swap.
$\mathcal{R}_6$	$\mathcal{R}_2$	Never swap.
$\mathcal{R}_6$	$\mathcal{R}_3$	Never swap.
$\mathcal{R}_6$	$\mathcal{R}_6$	Indifferent (no swap assumed).

Table IA.1: Optimal allocation policy (swap/no-swap) as a function of project location; with $z \leq \sigma$.

Let us take the perspective of BU i and define $\mathrm{E}\left[z_{i,P_i^*}\right]$ as the expected distance of α_i to the project optimally undertaken by i. This can be written as

$$
\begin{aligned}
&\mathrm{E}[z_{i,P_i^*}] = \\
&= \Pr\{\alpha_{P_i} \in \mathcal{R}_1\}\Big[\Pr\{\alpha_{P_j} \in \mathcal{R}_1\}\mathrm{E}[\min(z_{i,P_i}, z_{i,P_j})|\alpha_{P_i}, \alpha_{P_j} \in \mathcal{R}_1] + \\
&+ \Pr\{\alpha_{P_j} \in \mathcal{R}_6\}\mathrm{E}[z_{i,P_j}|\alpha_{P_j} \in \mathcal{R}_6] + \big(1 - \Pr\{\alpha_{P_j} \in \mathcal{R}_1 \cup \mathcal{R}_6\}\big)\,\mathrm{E}[z_{i,P_i}|\alpha_{P_i} \in \mathcal{R}_1]\Big] + \\
&+ \Pr\{\alpha_{P_i} \in \mathcal{R}_2\}\Big[\Pr\{\alpha_{P_j} \in \mathcal{R}_1\}\mathrm{E}[z_{i,P_j}|\alpha_{P_j} \in \mathcal{R}_1] + \\
&+ \Pr\{\alpha_{P_j} \in \mathcal{R}_6\}\mathrm{E}[z_{i,P_j}|\alpha_{P_j} \in \mathcal{R}_6] + \big(1 - \Pr\{\alpha_{P_j} \in \mathcal{R}_1 \cup \mathcal{R}_6\}\big)\,\mathrm{E}[z_{i,P_i}|\alpha_{P_i} \in \mathcal{R}_2]\Big] + \\
&+ \Pr\{\alpha_{P_i} \in \mathcal{R}_5\}\mathrm{E}[z_{i,P_i}|\alpha_{P_i} \in \mathcal{R}_5] + \Pr\{\alpha_{P_i} \in \mathcal{R}_6\}\mathrm{E}[z_{i,P_i}|\alpha_{P_i} \in \mathcal{R}_6]. \qquad \text{(IA.1)}
\end{aligned}
$$

The expression (as a function of parameters) of each of the components in equation (IA.1) is presented in Table IA.2.

We are omitting the explicit integration procedures, since all conditional distributions are uniform (in the relevant region), so probabilities and expected distances are generally simple functions of (region) arc length; the slightly more complex case is the computation of

Item	Expression
$\Pr\{\alpha_{P_i} \in \mathcal{R}_1\}$	$\frac{z}{2\sigma}$
$\Pr\{\alpha_{P_j} \in \mathcal{R}_1\}$	$\frac{z}{2\sigma}$
$\mathrm{E}[\min(z_{i,P_i}, z_{j,P_j})\|\alpha_{P_i}, \alpha_{P_j} \in \mathcal{R}_1]$	$\frac{z}{3}$
$\Pr\{\alpha_{P_j} \in \mathcal{R}_6\}$	$\frac{\sigma-z}{2\sigma}$
$\mathrm{E}[z_{i,P_j}\|\alpha_{P_j} \in \mathcal{R}_6]$	$\frac{\sigma-z}{2}$
$\mathrm{E}[z_{i,P_i}\|\alpha_{P_i} \in \mathcal{R}_1]$	$\frac{z}{2}$
$\Pr\{\alpha_{P_i} \in \mathcal{R}_2\}$	$\frac{\sigma-z}{2\sigma}$
$\mathrm{E}[z_{i,P_j}\|\alpha_{P_j} \in \mathcal{R}_1]$	$\frac{z}{2}$
$\mathrm{E}[z_{i,P_i}\|\alpha_{P_i} \in \mathcal{R}_2]$	$\frac{z+\sigma}{2}$
$\Pr\{\alpha_{P_i} \in \mathcal{R}_5\}$	$\frac{z}{2\sigma}$
$\mathrm{E}[z_{i,P_i}\|\alpha_{P_i} \in \mathcal{R}_5]$	$\frac{2\sigma-z}{2}$
$\Pr\{\alpha_{P_i} \in \mathcal{R}_6\}$	$\frac{\sigma-z}{2\sigma}$
$\mathrm{E}[z_{i,P_i}\|\alpha_{P_i} \in \mathcal{R}_6]$	$\frac{\sigma-z}{2}$

Table IA.2: Auxiliary table for derivation of equation (IA.2).

$\mathrm{E}[\min(z_{i,P_i}, z_{j,P_j})|...]$, where we used a standard result on order statistics for random variables drawn from independent uniform distributions.[1]

Inserting the expressions from Table IA.2 into equation (IA.1), and after a few steps of algebra, one obtains

$$\mathrm{E}\left[z_{i,P_i^*}\right] = \frac{1}{24\sigma^2}\left(-z^3 + 6\sigma z^2 - 6\sigma^2 z + 12\sigma^3\right), \tag{IA.2}$$

which implies equation (3a) in the proposition.

<u>Case 2:</u> $z > \sigma$

For this case let us make the additional assumption that $z \leq 2\sigma$. This assumption is made without loss of generality, since for $z > 2\sigma$ there cannot be any gains from diversification and

[1] The expected value of the kth order statistic for a sequence of n independent uniform random variables on the unit interval is given by

$$\frac{k}{n+k}.$$

In our case, $k = 1$ and $n = 2$ (the two projects), and the random variables have support $[0, z]$, which yields $\mathrm{E}[\min(z_{i,P_i}, z_{j,P_j})|...] = z/3$.

Location of α_{P_i}	Location of α_{P_j}	Optimal allocation policy
$\mathcal{R}_1$	$\mathcal{R}_2$	Never swap.
$\mathcal{R}_1$	$\mathcal{R}_3$	Never swap.
$\mathcal{R}_1$	$\mathcal{R}_4$	Never swap.
$\mathcal{R}_2$	$\mathcal{R}_2$	Swap if and only if $\alpha_{P_j} < \alpha_{P_i}$.
$\mathcal{R}_2$	$\mathcal{R}_3$	Never swap.
$\mathcal{R}_2$	$\mathcal{R}_4$	Never swap.
$\mathcal{R}_6$	$\mathcal{R}_2$	Never swap.
$\mathcal{R}_6$	$\mathcal{R}_3$	Never swap.
$\mathcal{R}_6$	$\mathcal{R}_4$	Never swap.

Table IA.3: Optimal allocation policy (swap/no-swap) as a function of project location; with $z > \sigma$.

the two-division conglomerate is simply a collection of two specialized business units, each undertaking its own projects (this corresponds to equation (3c) in the proposition). Let us again partition the circle into six regions, depicted in the right of Figure IA.1. Similarly as in the previous case, we define region $\mathcal{R}_1$ as the arc between 0 and $z - \sigma$, region $\mathcal{R}_2$ as the arc between $z - \sigma$ and σ, and so on. The location of the project generated by i can occur in regions 1, 2, or 3; the location of the project generated by j can occur in regions 2, 3, or 4. Table IA.3 shows the optimal allocation policy for each scenario.

Again let us take the position of BU i; we can then write

$$\begin{aligned}
&\mathrm{E}[z_{i,P_i^*}] = \\
&= \Pr\{\alpha_{P_i} \in \mathcal{R}_1\}\mathrm{E}[z_{i,P_i}|\alpha_{P_i} \in \mathcal{R}_1] + \Pr\{\alpha_{P_i} \in \mathcal{R}_6\}\mathrm{E}[z_{i,P_i}|\alpha_{P_i} \in \mathcal{R}_6] \\
&+ \Pr\{\alpha_{P_i} \in \mathcal{R}_2\}\Big[\Pr\{\alpha_{P_j} \in \mathcal{R}_2\}\mathrm{E}[\min(z_{i,P_i}, z_{i,P_j})|\alpha_{P_i}, \alpha_{P_j} \in \mathcal{R}_2] + \\
&+ (1 - \Pr\{\alpha_{P_i} \in \mathcal{R}_2\})\,\mathrm{E}[z_{i,P_i}|\alpha_{P_i} \in \mathcal{R}_2]\Big]. \qquad \text{(IA.3)}
\end{aligned}$$

The expression of each of the components in equation (IA.3) is presented in Table IA.4.

Inserting the expressions from Table IA.4 into equation (IA.3), and after a few steps of algebra, one obtains

$$\mathrm{E}\left[z_{i,P_i^*}\right] = \frac{1}{24\sigma^2}\left(z^3 - 6\sigma z^2 + 12\sigma^2 z + 4\sigma^3\right), \qquad \text{(IA.4)}$$

which implies expression (3b) in the proposition. □

Item	Expression
$\Pr\{\alpha_{P_i} \in \mathcal{R}_1\}$	$\frac{z-\sigma}{2\sigma}$
$\mathrm{E}[z_{i,P_i} \vert \alpha_{P_i} \in \mathcal{R}_1]$	$\frac{z-\sigma}{2}$
$\Pr\{\alpha_{P_i} \in \mathcal{R}_6\}$	$\frac{1}{2}$
$\mathrm{E}[z_{i,P_i} \vert \alpha_{P_i} \in \mathcal{R}_6]$	$\frac{\sigma}{2}$
$\Pr\{\alpha_{P_i} \in \mathcal{R}_2\}$	$\frac{2\sigma-z}{2\sigma}$
$\Pr\{\alpha_{P_j} \in \mathcal{R}_2\}$	$\frac{2\sigma-z}{2\sigma}$
$\mathrm{E}[\min(z_{i,P_i}, z_{j,P_j}) \vert \alpha_{P_i}, \alpha_{P_j} \in \mathcal{R}_2]$	$\frac{2z-\sigma}{3}$
$\mathrm{E}[z_{i,P_i} \vert \alpha_{P_i} \in \mathcal{R}_2]$	$\frac{z}{2}$

Table IA.4: Auxiliary table for derivation of equation (IA.4).

Proof of Proposition 2.

Let us start by conjecturing that the optimal segment distance is smaller than σ. Then we need to obtain the first-order condition with respect to equation (3a), which is

$$\frac{z^2}{8\sigma^2} - \frac{z}{2\sigma} + \frac{1}{4} = 0 \Leftrightarrow z^2 - 4z\sigma + 2\sigma^2 = 0.$$

The two roots of the above quadratic are given by, after a few steps of algebra,

$$z = \sigma\left(2 \pm \sqrt{2}\right).$$

The root with the plus sign before the square root term cannot be a solution, since it would imply $z^* \geq 2\sigma$. Therefore we are left with the other root, i.e. equation (4) in the proposition. The next step in the proof is to verify our initial conjecture that the optimal z cannot lie in the second branch of the profit function. To prove this, it is sufficient to show that equation (3b) is never upward-sloping in its domain:

$$-\frac{z^2}{8\sigma^2} + \frac{z}{2\sigma} - \frac{1}{2} \leq 0 \Leftrightarrow z^2 - 4\sigma z + 4\sigma^2 \geq 0 \Leftrightarrow (z - 2\sigma)^2 \geq 0,$$

which concludes the proof. □

Proof of Proposition 3.

We focus on the equilibrium where mergers take place (the other case is trivial). The solution to the firm's optimization problem (7) is a simple application of real options theory, where

the exercise threshold corresponds to a minimum level for the cash-flow rate of a diversified BU. This minimum cash-flow rate maps onto a region $[z_L, z_H]$ around the static optimum z^* (where $\pi_1^G(z_L) = \pi_1^G(z_H)$). The solution to the problem described in expression (7), given financial markets' equilibrium, needs to verify the following conditions (where for notational simplicity we set $\tau = 0$):

$$\begin{cases} rJ_2(z,t)\,dt = [\pi_1(z) - \beta]\;dt + \mathrm{E}_t[dJ(t)] \\ rJ_1(z,t)\,dt = \pi_1(z)\,dt + \mathrm{E}_t[dJ(t)] \\ rJ_0\,dt = \pi_0\,dt + \mathrm{E}_t[dJ(t)] \end{cases}$$

Given the assumed Poisson processes and the conjectured merger-acceptance probability q, the above system can be written as

$$\begin{cases} rJ_2(z,t) = [\pi_1(z) - \beta] + \lambda_2[J_0 - J_2(z)] & \text{(IA.5)} \\ rJ_1(z,t) = \pi_1(z) + \lambda_1[J_2(z) - J_1(z)] & \text{(IA.6)} \\ rJ_0 = \pi_0 + \lambda_0 q\left\{\mathrm{E}[J_1(z,t+dt)|z \in [\underline{z}, \overline{z}]] - J_0\right\}. & \text{(IA.7)} \end{cases}$$

Manipulation of equations (IA.5)-(IA.6) straightforwardly yields expressions (8)-(9) in the proposition. Using equation (9), we can write

$$\mathrm{E}[J_1(z,t+dt)|z \in [\underline{z}, \overline{z}]]$$

as

$$\int_{z_L}^{z_H} \left(\frac{1}{z_H - z_L}\right) J_1(z)\,dz = \frac{\overline{\pi}_1(r + \lambda_1 + \lambda_2) - \lambda_1\beta + \lambda_1\lambda_2 J_0}{(r+\lambda_1)(r+\lambda_2)}.$$

Inserting the above expression into equation (IA.7), and solving for J_0, one obtains equation (10) in the proposition. □

Proof of Proposition 4.

Let us begin with the second result in the proposition. Since in equilibrium the distribution of firms is stationary, it needs to be the case that the mass of good conglomerates becoming bad over an infinitesimal dt, $(1-p)(1-w)\lambda_1\,dt$, be the same as the mass of bad conglomerates refocusing, which is $(1-p)w\lambda_2\,dt$. Simplification of this equality yields expression (14) in the proposition. The first result obtains along similar lines. The mass of single-segment firms becoming diversified over an infinitesimal dt, $p\lambda_0 q\,dt$, must be the same as the mass of firms refocusing, which is $(1-p)w\lambda_2\,dt$. Using the expression for w and simplifying yields equation (13). Next we turn to the third result of the proposition, and let us start with the sufficiency argument. If $q = 0$ then no single-segment firm ever wants to merge, even in the

best possible case, i.e., a match where $z = z^*$. We also know that in this economy $J_0 = \pi_0/r$. Combining this with the optimality of the decision not to merge in the best possible case, we have the following condition:

$$J_1(z^*) \leq \frac{\pi_0}{r} \Leftrightarrow \frac{\pi_1(z^*)(r + \lambda_1 + \lambda_2) - \lambda_1\beta + \lambda_1\lambda_2 J_0}{(r + \lambda_1)(r + \lambda_2)} \leq \frac{\pi_0}{r},$$

where we used equation (9). Replacing π_0 and $\pi_1(z^*)$ by their expressions as a function of primitives σ and ϕ (equations (2) and (5)); and after a few steps of algebra, yields the result $\phi\sigma \leq C$. For the necessity part of the proof we note that $q = 0$ could not be an equilibrium if $\phi\sigma > C$, since, by the argument above, there would be some mergers worth executing (which is inconsistent with $q = 0$). $\square$

Proof of Proposition 5.

First note that the equilibrium exists and is unique for $\phi\sigma \leq C$, where C is defined in Proposition 4. In this simple equilibrium, irrespective of starting history with some conglomerates or not, the steady state comprises all firms being single-segment (i.e., $p = 1$). Next let us establish that an equilibrium always exists for $\phi\sigma > C$. Since $J_1(z^*) > J_0 > J_1(0)$, and given continuity, this implies that there exists $\{z_L, z_H\}$ such that $J_1(z_L) = J_1(z_H) = J_0$. Uniqueness follows from continuity and the fact that the equilibrium is unique at $\phi\sigma \leq C$ (see, e.g., Garcia and Zangwill (1982) for more technical details). $\square$

IA.2 Simplified dynamic model

This section presents a simplified version of the stationary dynamic model of section III.B.2, and serves the purpose of illustrating in a clear way how the dynamic search-and-matching component of the model works. The key difference is that we assume a much simpler synergy technology. Specifically, the profit rate of specialized firms is still constant (and denoted by π_0), but the profit rate of (good) diversified firms is $\pi_0 + x$, where synergies x are drawn from a uniform distribution with support $[0, \overline{x}]$ at the time of matching. This stands in contrast with the more complex modeling of synergies as a function of segment distance employed in the main version of the model.

A second simplification is that once conglomerates become bad (which occurs with intensity λ_1, as before), they refocus immediately (i.e., $\lambda_2 \to \infty$). The matching intensity of specialized firms is still denoted as λ_0 and the interest rate as r.

The standard equilibrium conditions apply to the two branches of the value function, J_0 for specialized firms and $J_1(x)$ for conglomerates:

$$
\begin{aligned}
rJ_0\,dt &= \pi_0\,dt + \mathrm{E}_t[dJ_0] \\
rJ_1(x)\,dt &= (\pi_0 + x)\,dt + \mathrm{E}_t[dJ_1(x)]
\end{aligned}
$$

Given our assumptions, the above corresponds to

$$
J_0 = \frac{\pi_0 + \lambda_0 q \mathrm{E}[J_1(x)]}{r + \lambda_0 q} \tag{IA.8}
$$

$$
J_1(x) = \frac{\pi_0 + x + \lambda_1 J_0}{r + \lambda_1}, \tag{IA.9}
$$

where q (as in the main model) denotes the probability of match/merger acceptance.

As usual in real-options models, we need to find the threshold strategy x^*, such that mergers are accepted for all synergy rates $x > x^*$. Noting that the average synergy rate conditional on a merger happening is $(x^* + \overline{x})/2$, we can use equation (IA.9) and write

$$
\mathrm{E}[J_1(x)] = \frac{\pi_0 + (x^* + \overline{x})/2 + \lambda_1 J_0}{r + \lambda_1}. \tag{IA.10}
$$

Inserting equation (IA.10) in equation (IA.8), and after some algebra, yields

$$
J_0 = \frac{1}{r}\left\{\frac{\pi_0(r + \lambda_1) + \lambda_0 q\left[\pi_0 + (x^* + \overline{x})/2\right]}{r + \lambda_0 q + \lambda_1}\right\} \tag{IA.11}
$$

The equilibrium condition that characterizes x^* is $J_1(x^*) = J_0$. Combining equations (IA.9) and (IA.11), this condition can be written as

$$\pi_0 + x^* = \frac{\pi_0(r + \lambda_1) + \lambda_0 q \left[\pi_0 + (x^* + \overline{x})/2\right]}{r + \lambda_0 q + \lambda_1}.$$

After some algebra, and noting that $q = 1 - x^*/\overline{x}$, the above yields a quadratic in x^*:

$$(x^*)^2 \frac{\lambda_0}{2\overline{x}} - x^*(r + \lambda_1 + \lambda_0) + \frac{\lambda_0 \overline{x}}{2} = 0$$

It is straightforward to check that the positive root of the quadratic above implies $x^* > \overline{x}$, which is impossible. Thus we are left with the negative root, which after some simplification can be written as follows:

$$x^* = \overline{x}\left(a - \sqrt{a^2 - 1}\right), \tag{IA.12}$$

where

$$a := 1 + \frac{r + \lambda_1}{\lambda_0}. \tag{IA.13}$$

The equilibrium threshold x^* has some intuitive properties. First, it is straightforward to see from equation (IA.12) that x^* is proportional to $\overline{x}$. Second, it can easily be checked that $x^* \in (0, \overline{x})$; that is, the economy always has some specialized firms and some diversified firms. Third,

$$\frac{\partial x^*}{\partial a} = \overline{x}\left(1 - \frac{1}{\sqrt{1 - 1/a^2}}\right) < 0,$$

which implies:

- x^* increases with λ_0. The intuition is that if matches are more likely, then firms can afford to be more demanding when accepting a merger partner.

- x^* decreases with r. To understand the intuition for this result, suppose $r \to \infty$; then continuation value is worthless and all that firms care about are immediate merger gains, which implies that *any* merger is good enough (since $x \geq 0$). In other words, with high r option value is non-existent and therefore exercise is immediate (standard NPV rule applies).

- x^* decreases with λ_1. If λ_1 is very low, then firms are stuck with their match for a long time, on average. Therefore, they are more demanding about whom they merge with. In contrast, if mergers are very short-lived (high λ_1), then the opportunity cost of merging with a low-synergy partner is low, which implies that firms are not very demanding about whom they pair up with.

IA.3 Details about calibration with time-varying σ

IA.3.1 Solution method

With time-varying σ firms still face the optimization problem described in (7), except now merger-acceptance policies are time-varying. The only caveat to the similarity in optimization problems is that for the non-stationary model, some firms could actually merge at some point in time and refocus later, *even without turning into bad conglomerates*. This could take place for pairs that were close to the exercise boundary, and for whom the opportunity cost of not being in the mergers market increases over time (as σ decreases). This caveat notwithstanding, and for simplicity, we assume that only bad conglomerates can refocus.

We solve the model using the following steps:

1. We first determine a level of σ for date 0, and we choose a value that is high but still produces strictly positive average profits for single-segment firms (see equation (2)). Specifically, we set this magnitude at 0.26. Even for this higher value of σ, assumption 1 is verified:
$$\pi_1(z^*(\phi,\sigma);\phi,\sigma) - \pi_0(\phi,\sigma) < \beta \Leftrightarrow 0.13 < 0.39.$$

2. Using the starting value for σ we solve the steady-state model and obtain distributions for firm types, namely the proportion of single-segment firms p_0 and the initial fraction of bad conglomerates w_0. This procedure allows us to use initial conditions that are not excessively arbitrary.

3. We then choose a terminal time horizon T, which we pick to be 150 years, and a terminal level of σ (set at 0.07, which implies an output growth rate of 2% for single-segment firms, within the relevant time period of 1998-2013). We conjecture that the terminal level of σ is such that mergers no longer take place on the last period, which allows us to compute J_0 at the terminal date T simply as $\pi_{0,T}/r$ (implicitly we assume that σ is constant for periods later than T). This is an important input for the calculation of value functions in previous periods. Similarly, we can compute theoretical values for $J_1(z)$ and $J_2(z)$ at time T using equations (9) and (8).

4. We discretize time using an interval of length δ_t (1 week in our numerical implementation), and obtain each relevant value function, under the assumption of a particular policy path $\{z_{L,t}, z_{H,t}\}_{t\in[0,T]}$. In particular, value functions are obtained recursively, by using the following system of finite differences (these basically discretize the non-

stationary version of the differential equations presented in the proof of Proposition 3):

$$
\begin{aligned}
J_2(z,t) &= (\pi_1(z,t)-\beta)\delta_t + (1-r\delta_t)\left[\lambda_2\delta_t J_0(t+1) + (1-\lambda_2\delta_t)J_2(z,t+1)\right] \\
J_1(z,t) &= \pi_1(z,t)\delta_t + (1-r\delta_t)\left[\lambda_1\delta_t J_2(z,t+1) + (1-\lambda_1\delta_t)J_1(z,t+1)\right] \\
J_0(t) &= \pi_0(t)\delta_t + (1-r\delta_t)\left[\lambda_0\delta_t q(t+1)\mathrm{E}[J_1(z,t+1)|z\in[z_{L,t},z_{H,t}]]+\right. \\
&\quad \left.+(1-\lambda_0\delta_t q(t+1))J_0(t+1)\right]
\end{aligned}
$$

5. We iterate the policy function using the optimal decision rule (i.e, merge only if it creates value), and obtain convergence.

6. Given the sequence of merger-acceptance policies, we compute the laws of motion for each mass of firm types; we denote the time-t density (at z) of bad conglomerates as $c_b(z,t)$ and the density of good conglomerates as $c_g(z,t)$:

$$
\begin{aligned}
\frac{dp(t)}{dt} &= \int_0^{1/2} c_b(z,t-1)\lambda_2\, dF(z) - p(t-1)\lambda_0 q(t) \\
\frac{dc_g(z,t)}{dt} &= p(t-1)\lambda_0 \mathbb{1}_{z\in[z_{L,t},z_{H,t}]}\, dF(z) - c_g(z,t-1)\lambda_1 \\
\frac{dc_b(z,t)}{dt} &= c_g(z,t-1)\lambda_1 - c_b(z,t-1)\lambda_2,
\end{aligned}
$$

   where $F(z)$ is the uniform distribution with support $[0,1/2]$.

7. With the firm-type distributions and value functions it is straightforward to obtain all outputs. The relevant period is identified by finding the time step at which $\sigma = 0.2$ (the choice in the steady-state calibration) and determining that to be the midpoint of the 1998-2013 interval.

IA.3.2 Additional outputs

Table IA.5 shows that the magnitudes implied by the steady-state model in terms of levels are close to those generated by the non-stationary calibration.

The main differences are a higher value of single-segment firms J_0 (as intended, see discussion in section IV), as well as lower average diversifying-merger returns (although calibrated announcement returns are 87% of the average return in data, which is a good fit). The higher J_0 is to be expected, since now value functions incorporate growth in cash flows. Furthermore, a higher J_0 makes returns to diversification lower.

Table IA.5: Model Outputs and Data: Steady-State vs. Non-Stationary model. The table shows key moments, both in the steady-state (SS) calibration and the non-stationary (NS) calibration (averages across 1998-2013 period), as well as data/targets. "Prop. Congs." is the proportion of assets in the economy allocated to diversified firms; "Single-Seg. Value" is the market-to-book ratio of single-segment firms; "Div. Discount" is the average valuation difference between a conglomerate and a comparable portfolio of specialized firms; "Probab. of M&A" stands for the likelihood that a single-segment BU engaged in at least one merger deal over a one-year period; "Av. Div. Returns" stands for the average announcement returns of diversifying mergers; and "Refocusing Rate" refers to the fraction of conglomerates becoming single-segment firms over a one-year period.

Moment	SS-Calibration	NS-Calibration	Data/target
Prop. Congs.	59%	59%	59%
Single-Seg. Value	2.9	3.4	2.5 (SS) / 3.1 (NS)
Div. Discount	3.4%	4.2%	3.3%
Probab. of M&A	7.5%	7.1%	6.0%
Av. Div. Returns	4.1%	3.3%	3.8%
Refocusing Rate	4.8%	4.9%	7.6%

IA.3.3 Robustness check

This section presents a simple robustness check of our results, where we ask how much initial conditions matter. To address this issue we simulate the non-stationary model, but adopting rather extreme initial conditions, in particular that all firms are single-segments; and that all conglomerates are good.

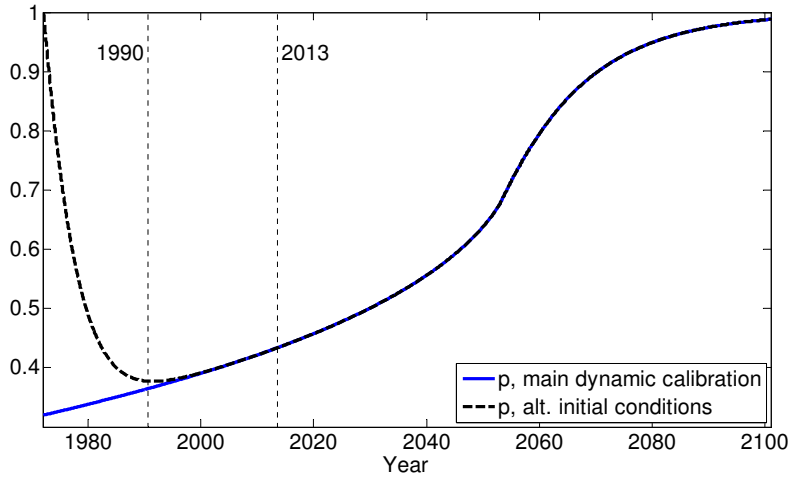

Figure IA.2: Initial Conditions: Robustness Check. The figure plots the evolution of p under alternative initial conditions: 99.9% of all firms are single-segment at time 0; and 99.9% of all conglomerates are good at time 0.

Figure IA.2 plots the evolution of p, the fraction of single-segment firms, for this new simulation; and compares this output with the output of our main non-stationary calibration. In particular, if one focuses on the relevant period 1990-2013, one observes little difference

between the main simulation path and the alternative one. For the sake of space we do not report other magnitudes, but the differences are also small. The key takeaway of this analysis is that our results do not seem to be driven by our treatment of initial conditions, the effect of which vanishes relatively quickly.

IA.4 Diversification and R&D Scope

If we assume that the degree of specialization (inverse of σ in the model) is different across firms or industries, then a simple extension of the model would predict that firms with lower intensity of specialization are more diversified. We can directly test such prediction in two ways: First, we can measure the intensity of specialization by seeing whether firms engage in research and development and patenting activity or not. We conjecture that R&D and patenting firms are more active in searching for and finding projects, and thus they would have lower specialization, and thus benefit more from project reallocations occurring in a conglomerate. We thus predict a positive coefficient between R&D and the number of segments, and between the patenting activity of a firm and its number of segments.

Second, we can use the scope of a firm's R&D as a proxy for the intensity of technological specialization. Specifically, we can measure how a firm's R&D is applicable to other industries, by computing patent originality and generality. We predict that firms with greater patent generality and originality would be associated with a greater number of segments, because a wider scope of R&D production would make project reallocation more valuable.

We thus test these two predictions using Compustat Segments to measure the number of segments of public firms in the US. We use Compustat Fundamentals Annual to measure the intensity of R&D, measured as a dummy equal to one if a firm reports any R&D in the year, and zero otherwise. We use the patent data from Kogan, Papanikolaou, Seru, and Stoffman (2017) to compute the patent-related variables. Patenting Firm Dummy is a variable equal to one if a firm files at least a patent to the USPTO in the year, and zero otherwise. For each filed patent, we compute originality and generality, following Trajtenberg, Henderson, and Jaffe (1997): Generality measures the extent to which a patent is cited by patents from a broad spectrum of industries in the future. Originality is a measure of the breadth of the industries which patents cited by the original patent belong to. We adjust for potential downward bias inherent in Herfindahl index-type of measures following Hall (2005). As industry classification, we use the seven broad NBER technological categories defined in Hall, Jaffe and Trajtenberg (2001).

Table IA.6 presents a set of coefficient estimates of eight OLS regression specifications, where the dependent variable is the number of segments for each firm-year observation. Columns (1) and (2) show that cross-sectionally, R&D and patenting firms indeed are more diversified: firms that report R&D expenditures in financial statements have 0.1 more segments than firms with no R&D. Similarly, firms that file patents to the USPTO have 0.23 more segments than non-patenting firms. Columns (3) and (4) show that firms are more diversified if their

patents have a broader interest across many industries, measured by the originality and the generality of their patents. In columns (5) through (8) we re-run the regressions in the previous columns, but adding firm fixed effects, thus correlating the change in diversification within the same firm over time with the proxies for the level of technological specialization. Except for generality, we find similar results: As firms become more technically specialized over time, they tend to become less diversified.

We openly recognize that the allocation of R&D and patenting activity is not randomly allocated to firms, so our analysis should be interpreted as an association between the level of technical specialization and corporate diversification, and not a causal relationship. Nonetheless, the evidence is consistent with the prediction of the model.

Table IA.6: Diversification and R&D Scope The dependent variable in all columns is the number of segments for each firm-year in the Compustat Segments File. R&D Firm Dummy is a variable equal to one if the firm reports any R&D expenditure in the year. Patenting Firm Dummy is a variable equal to one if the firm has filed for a patent to the United States Patent and Trademark Office in the year, and zero otherwise. Average Originality and Average Originality are the average originality and generality of all the patents produced by a firm in the year. The patent originality (generality) measure follows Trajtenberg, Henderson, and Jaffe (1997) and is defined as one minus the Herfindahl Index of cited (citing) patent concentration across the seven NBER technological categories defined in Hall, Jaffe and Trajtenberg (2001). The measures are corrected for the downward bias in Herfindahl measures as explained in Hall (2005). The patent data comes from Kogan, Papanikolaou, Seru, and Stoffman (2017). Standard errors are clustered at the firm level. *, **, and *** refer to p-value significance at the 1%, 5%, and 10% respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
R&D Firm Dummy	0.106***				0.069***			
	(7.65)				(4.98)			
Patenting Firm Dummy		0.228***				0.055***		
		(11.02)				(5.83)		
Patent Originality (Av)			0.218***				0.038*	
			(5.43)				(1.74)	
Patent Generality (Av)				0.172***				0.017
				(4.48)				(0.80)
Total Assets (log)	0.131***	0.123***	0.275***	0.282***	0.088***	0.087***	0.220***	0.228***
	(37.33)	(36.90)	(22.54)	(21.98)	(34.10)	(33.71)	(21.26)	(21.28)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	No	Yes	Yes	Yes	Yes
Adj. R^2	0.146	0.150	0.289	0.292				
N	233,943	233,943	36,760	33,663	233,943	233,943	36,760	33,663

IA.5 Additional relatedness trends

Figure IA.3 shows the evolution of alternative relatedness measures. The top panel shows the evolution of vertical relatedness, which, following Fan and Lang (2000) measures the intensity of the vertical connection between the primary-segment industry and the secondary-segment industries. The bottom panels show the evolution of the weight of related segments, as a fraction of the total number of segments. In the bottom-left (bottom-right) panel, related segments are the number of unique segments of a conglomerate using the detailed 1997 Input-Output industry classification system (4-digit SIC system), minus the number of unique segments of a conglomerate using the 3-digit 1997 Input-Output industry classification system (3-digit SIC system), following Berger and Ofek (1995). All three relatedness measures exhibit an increasing trend, in line with our main (un)relatedness measure (segment distance).

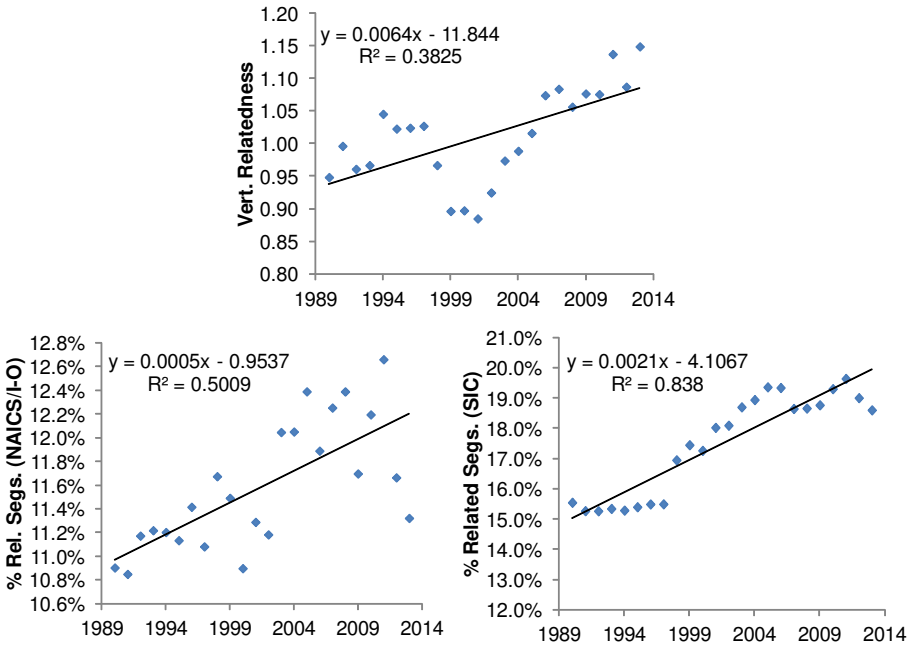

Figure IA.3: Evolution of Relatedness: Alternative Empirical Measures. The top panel shows the evolution of vertical relatedness, computed following Fan and Lang (2000). The bottom-left (bottom-right) panel shows the evolution of the ratio between the number of related segments, based on the NAICS/I-0 (SIC) classification. All variables are defined in detail in section IA.7.

IA.6 Extension: model with truncated matching

In this section we extend our model to allow for a truncation in the distribution of merger matches. In particular, we assume that matches only occur within a neighborhood of the firm's business environment. We define this truncation in the simplest possible way, requiring that matches occur uniformly in the interval $[0, z_{\max}]$. When this new constraint is binding, we are able to partly match the cross-sectional empirical pattern presented in section V.A.3, namely that excess value increases in segment distance. Given the focus on the cross section, we calibrated the extended model only for the steady-state case. We expand the set of moments from the baseline case to include the difference in excess value across high- and low-segment-distance conglomerates,

$$\Delta\text{EXCESS_VALUE} := \text{EXCESS_VALUE}|_{z>\text{median}} - \text{EXCESS_VALUE}|_{z\leq\text{median}} \tag{IA.14}$$

which in our data is about 0.087.

Table IA.7: Calibrated Parameters: Baseline vs. Truncated model. The table shows the magnitude of each parameter, both in the baseline steady-state calibration and the truncated steady-state calibration.

Description	Parameter	Baseline	Truncated
Discount rate	r	0.10	0.10
Likelihood of merger matches	λ_0	0.31	0.15
Likelihood of becoming bad conglomerate	λ_1	0.07	0.06
Likelihood of refocusing bad congs.	λ_2	0.25	0.21
Overhead cost of bad conglomerates	β	0.39	0.26
Cost of project technological mismatch	ϕ	7.20	8.30
Inverse of technological specialization	σ	0.20	0.20
Maximal matching distance	$z_{\max}$	n.a.	0.05

Table IA.7 summarizes the choice of parameters, and assumption 1 is once more non-binding:

$$\pi_1(z^*(\phi,\sigma);\phi,\sigma) - \pi_0(\phi,\sigma) < \beta \Leftrightarrow 0.11 < 0.26$$

Table IA.8 reports key levels (compares to Table 2 for the main model). The truncated model can fit data well (better than the baseline model in some dimensions, worse in others), and in particular explains 60% of the cross-sectional relation between segment distance and excess value (Δ EXCESS_VALUE is 5.4% in the model and 8.7% in data). The main difference in the parameters we were already using in the main model is the choice of λ_0. In the truncated model, $\lambda_0 = 0.15$, whereas $\lambda_0 = 0.31$ in the main model. The difference is explained by the fact that in the main model, there are matches that occur beyond the useful range, that is,

Table IA.8: Model Outputs and Data: Baseline vs. Truncated model. The table shows key moments, both in the baseline steady-state calibration and the truncated steady-state calibration, as well as data/targets. "Prop. Congs." is the proportion of assets in the economy allocated to diversified firms; "Single-Seg. Value" is the market-to-book ratio of single-segment firms; "Div. Discount" is the average valuation difference between a conglomerate and a comparable portfolio of specialized firms; "Probab. of M&A" stands for the likelihood that a single-segment BU engaged in at least one merger deal over a one-year period; "Av. Div. Returns" stands for the average announcement returns of diversifying mergers; "Refocusing Rate" refers to the fraction of conglomerates becoming single-segment firms over a one-year period; and "Δ Excess Value" is the difference in excess value between above-median-segment-distance and below-median-segment-distance conglomerates.

Moment	Baseline	Truncated	Data/target
Prop. Congs.	59%	59%	59%
Single-Seg. Value	2.9	1.8	2.5
Div. Discount	3.4%	3.2%	3.3%
Probab. of M&A	7.5%	6.5%	6.0%
Av. Div. Returns	4.1%	6.4%	3.8%
Refocusing Rate	4.8%	4.2%	7.6%
Δ Excess Value	0.0%	5.4%	8.7%

at distances bigger than 2σ (unlike with truncated matching). Therefore, in order to obtain the same rate of merger activity, there need to be more matches taking place.

IA.7 Summary statistics and variable definitions (NAICS/I-O)

- ASSETS: The total assets of a company (Source: AT variable in Compustat). This variable is adjusted for goodwill (Source: GDWL variable in Compustat), following Custódio (2014).

- CAPEX: Funds used for additions to PP&E, excluding amounts arising from acquisitions (Source: CAPEX variable in Compustat).

- EBIT (Earnings Before Interest and Taxes): Net Sales, minus Cost of Goods Sold minus Selling, General & Administrative Expenses minus Depreciation and Amortization (Source: EBIT variable in Compustat).

- EXCESS_ASSETS: The log-difference between the assets of a conglomerate and the assets of a similar portfolio of single-segment firms (Source: Compustat Segments and Authors' Calculations).

- EXCESS_CAPEX/SALES: The difference between the capex/sales of a conglomerate and the capex/sales of a similar portfolio of single-segment firms. We did not take the log difference as in other excess measures because in a few cases capex/sales is negative (Source: Compustat Segments and Authors' Calculations).

- EXCESS_CENTRALITY: The log-difference between the closeness centrality of a conglomerate and the assets-weighted closeness centrality of a similar portfolio of single-segment firms, using the detailed 1997 Input-Output industry classification system (Source: Compustat, Compustat Segments, BEA, and Authors' Calculations). We scale the raw variable by its unconditional mean.

- EXCESS_EBIT/SALES: The difference between the EBIT/sales of a conglomerate and the EBIT/sales of a similar portfolio of single-segment firms. We did not take the log difference as in other excess measures because in many cases EBIT/sales is negative (Source: Compustat Segments and Authors' Calculations).

- EXCESS_VALUE: The log-difference between the market-to-book ratio of a conglomerate (adjusted for goodwill following Custódio (2014)) and the assets-weighted market-to-book ratio of a similar portfolio of single-segment firms, using the detailed 1997 Input-Output industry classification system (Source: CRSP, Compustat, BEA, and Authors' Calculations).

- MARKET_TO_BOOK_RATIO: The sum of total goodwill-adjusted assets (AT-GDWL), following Custódio (2014), minus the book value of equity (BE) plus the market capitalization (Stock Price at the end of the year (PRCC_F) times the number of shares outstanding (CSHO)), divided by the total assets adjusted by goodwill (AT-GDWL) (Source: Compustat).

- NUM_OF_SEGS: The number of unique segments of a conglomerate using the detailed 1997 Input-Output industry classification system (Source: Compustat Segments and BEA).

- REL_SEGS: The number of unique segments of a conglomerate using the detailed 1997 Input-Output industry classification system, minus the number of unique segments of a conglomerate using the 3-digit 1997 Input-Output industry classification system, following Berger and Ofek (1995) (Source: Compustat Segments and BEA).

- SALES: Gross sales reduced by cash discounts, trade discounts, and returned sales (Source: SALE variable in Compustat).

- SEG_DIST: The distance between any two industries the conglomerate participates in, averaged across all pairs (Source: Compustat Segments, BEA, and Authors' Calculations). We scale the raw variable by its unconditional mean.

- VERT_REL: Constructed following Fan and Lang (2000). Measures the average input-output flow intensity between each of the conglomerate's non-primary segments and the conglomerate's primary segment; averaged across all non-primary segments. (Source: Compustat Segments, BEA, and Authors' Calculations). We scale the raw variable by its unconditional mean.

- WEIGHT_REL_SEGS: The ratio of Related Segments by Number of Segments (Source: Authors' Calculations).

Table IA.9: Summary Statistics. The table presents summary statistics for each variable, comprising the period 1990-2013.

Panel A: Conglomerates

Variable	Mean	Std. Dev.	Min.	Max.	#Obs.
MARKET_TO_BOOK_RATIO	1.91	2.04	0.48	55.47	29,221
EXCESS_VALUE	-0.32	0.72	-3.67	7.89	29,221
SEG_DIST	1.00	0.56	0.03	4.40	29,221
EXCESS_CENTRALITY	1.00	0.12	0.85	2.16	29,221
VERT_REL	1.00	2.70	0	24.80	29,221
NUM_OF_SEGS	2.61	0.94	2	10	29,221
WEIGHT_REL_SEGS	0.12	0.20	0	0.86	29,221
ASSETS	4,560	16,269	0.02	492,735	29,221
EBIT/SALES	-0.14	8.72	-1,018	642.3	28,407
CAPEX/SALES	0.14	2.89	-0.94	433.1	28,881
EXCESS_ASSETS	-0.10	2.37	-10.78	10.62	29,221
EXCESS_EBIT/SALES	3.67	18.70	-1,018	720.5	28,395
EXCESS_CAPEX/SALES	-0.71	6.92	-282.5	433.0	28,870

Panel B: Single-Segment Firms

Variable	Mean	Std. Dev.	Min.	Max.	#Obs.
MARKET_TO_BOOK_RATIO	3.14	4.90	0.48	63.41	95,348
EXCESS_VALUE	-0.28	0.70	-3.81	3.47	95,348
ASSETS	1,017	4,923	0.001	244,193	95,348
EBIT/SALES	-7.35	175.9	-28,838	5,638	88,205
CAPEX/SALES	1.23	47.15	-17.92	7,826	94,027

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