Supplement to

"The Effects of Entry on Incumbent Innovation and Productivity"

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Review of Economics and Statistics, Volume 91, Issue 1 (February 2009), pp. 20-32.

Section 1 – Theoretical Explanation for Heterogeneity in Entry Effects

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1 Theoretical Explanation for Heterogeneity in Entry Effects

This section provides the Schumpeterian growth model with entry, building on Acemoglu et al. (2006) and Aghion et al. (2001). Aghion et al. (2005b) present a closely related model. A simplified version of the model below, one with a fixed entry probability, is sketched in Aghion et al. (2004), Aghion and Griffith (2005) or Aghion and Howitt (2006).

1.1 Basic Model

In each period t a final good, henceforth the numéraire, is produced under perfect competition using a continuum of intermediate inputs, according to the technology:

$$y_t = \int_0^1 A_t(i)^{1-\alpha} x_t(i)^{\alpha} \; di, \; \alpha \in (0,1), \tag{1}$$

where $x_t(i)$ denotes the quantity of the intermediate input produced in sector i and $A_t(i)$ is the productivity parameter associated with the latest version of that input.

For each intermediate product there are two firms capable of producing an innovation. Intermediate producers live for only one period, and property rights over their technological capabilities are transmitted within dynasties. The final good is used as capital in the production of intermediate goods with a one-for-one technology. We assume Bertrand competition within each intermediate sector.

In any sector where both firms have access to the same technology, Bertrand competition implies zero profits. In any sector where one firm (the "leader") has a better technology than the other (the "laggard"), only the leader will actively produce. As shown in Acemoglu et al. (2006), the equilibrium profit for each leader takes the form:

$$\pi_t(i) = \delta A_t(i), \quad \delta = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}. \tag{2}$$

1.2 Technological states, innovation, and entry

The world's "technological frontier" at the *end* of each period t is characterized by a technology parameter $\overline{A}_t$ which grows at the exogenous rate $\gamma - 1 > 0$:

$$\bar{A}_t = \gamma \bar{A}_{t-1}.$$

At the *beginning* of period t intermediate firms can be of three types. Firms of type 1 operate at the current frontier, with a productivity level $A_{t-1}(i) = \bar{A}_{t-1}$. Type-2 firms are one step behind the frontier, with $A_{t-1}(i) = \bar{A}_{t-2}$, and type-3 firms are two steps behind, with $A_{t-1}(i) = \bar{A}_{t-3}$.

Innovation allows an incumbent firm to increase its productivity by the factor γ and thereby to keep up with growth of the frontier.[1] The cost of technology adoption is quadratic in its hazard rate and also proportional to the targeted level of productivity. More specifically, by incurring a cost

$$c_{jt} = c \cdot \left(z^2/2\right) \bar{A}_{t-j}, \; c > 0,$$

at the beginning of period t, a type-j incumbent, where $j \in \{1, 2\}$, can increase its productivity with probability z by the factor γ within that period, adopting the next most productive technology. With probability $1 - z$ the incumbent's productivity does not increase, and lags by $j + 1$ steps behind the new frontier. The most backward (type-3) firms are automatically upgraded by the factor γ. This reflects the idea that the cost of technological adoption becomes negligible for sufficiently mature technologies.

In each period and intermediate sector, there is one outside producer that can pay for an entry opportunity. We focus on technologically advanced entry; thus when entry occurs

[1] The assumption of "step-by-step" technological progress is made here for the sake of tractability. As in Aghion et al. (2001), this assumption avoids having to deal with asymmetries in the decision problems of firms at different distances from the technological frontier. If we allowed innovating type-2 firms to catch up with the frontier with sufficiently high probability the discouragement effect of entry on type-2 firms would turn into an escape-entry effect. In that case, our model would predict higher rates of innovation and productivity growth for type-2 firms than for type-1 firms, a prediction which is not borne by our data and empirical analysis.

it takes place at the *new* frontier $\bar{A}_t$.[2] An entrant will steal all the market and become the new leading firm unless the incumbent leader also has the frontier technology $\overline{A}_t$ after the innovation process described above, in which case we assume that the incumbent retains the entire market.[3]

Suppose that in an industry where the current leader is a type-j firm, entrants at time t need to pay the following entry fee to get an entry opportunity:

$$F_{jt} = \lambda \overline{A}_t + \eta(\overline{A}_t - \overline{A}_{t-j}),$$

where $j \in \{1, 2, 3\}$ and λ is random and uniformly distributed between 0 and Λ. The term in η reflects the additional cost that may arise for an entrant that brings up to frontier level a sector that was initially further below that frontier. In particular a high, positive η will tend to make the equilibrium probability of entry into an industry a decreasing function of the industry's initial distance to frontier, whereas the opposite will hold if η is small or equal to zero. Our main predictions turn out to be independent of whether η is high or low.

The probability of entry in a type-j sector is equal to the probability that the potential entrant pays the cost of entry, which in turn is the probability that the entrant's expected profit is greater than the entry fee F_{jt}.

In a type-2 or type-3 sector, where the expected profit of an entrant is $\delta \overline{A}_t$:

$$p_j = pr(\delta \overline{A}_t > F_{jt}) = \frac{\delta - \eta(1 - 1/\gamma^j)}{\Lambda}, \; j \in \{2, 3\}. \tag{3}$$

In a type-1 sector, the expected profit of an entrant is $\delta \overline{A}_t(1 - z_1)$, where z_1 denotes the probability that a type-1 incumbent leader innovates. In the main text we showed that this

[2] More generally, one can think of several potential entrants with heterogeneous and a priori uncertain productivities, who are racing for entry into a particular industry. As long as at least one potential entrant has a high productivity realization $\overline{A}_t$, the analysis and comparative static results will remain the same as if we assume only one potential entrant with productivity $\overline{A}_t$. See section 4.4.1 (IVD) in the paper for a discussion of other forms of entry.

[3] The following sequential game between incumbent firms and potential entrants provides foundation for this assumption: The entrant must pay a small entry fee to enter and can decide whether to pay this fee after observing the post-innovation technology of the incumbent. Assuming that Bertrand competition takes place after entry, the entrant will find it profitable to pay the entry fee and appropriate the local market if the incumbent is expected to lag behind the entrant. If the incumbent is, instead, expected to compete on an equal footing with the entrant, then the entrant will find it optimal not to pay the entry fee.

innovation probability itself depends upon the entry threat p_1, with

$$z_1 = \delta(p_1 + \gamma - 1)/c.$$

Thus, the probability p_1 must satisfy the fixed point equation:

$$p_1 = pr(\delta \overline{A}_t(1 - z_1) > F_{1t}) = \frac{\delta - \delta^2(\gamma - 1)/c - \eta(1 - 1/\gamma) - \delta^2 p_1/c}{\Lambda}, \tag{4}$$

or equivalently

$$p_1 = \frac{\delta - \delta^2(\gamma - 1)/c - \eta(1 - 1/\gamma)}{\Lambda + \delta^2/c}. \tag{5}$$

Therefore, all probabilities p_j denoting the probability that the potential entrant pays the cost of entry in a state-j sector are decreasing in the common entry cost parameter Λ, namely $p'_J(\Lambda) < 0$ with $j \in \{1, 2, 3\}$.

Note that incumbent laggards will never invest in innovation, because an innovation would at best allow the firm to catch up to its rival and would still leave the firm with zero profits. Note also that in steady state there are no intermediate sectors in which the incumbents are both type-1 or both type-2. This is because such a ("level") sector would have to have been level in the previous period, since non-innovating laggards never catch up to their leader, whereas innovation and entry will eventually unlevel the sector.

Thus, in the long run, all intermediate sectors will be in one of only three possible "states" at the beginning of any period: (a) state-1 sectors are those with a type-1 leader; (b) state-2 sectors are those with a type-2 leader and (c) state-3 sectors are those with two type-3 incumbents.

1.3 Equilibrium innovation

Consider the R&D decisions of incumbent leaders in state-1 and state-2 sectors.[4]

- A state-2 leader, with $A_{t-1}(i) = \bar{A}_{t-2}$, chooses its investment z to maximize the expected net profit gain from innovation minus the R&D effort cost, that is:

$$\max_z \{\delta z (1 - p_2) \bar{A}_{t-1} - c\left(z^2/2\right) \bar{A}_{t-2}\},$$

[4] Recall that laggards do not innovate and type-3 firms are automatically upgraded without investing.

from which the first order condition yields:

$$z = (\delta/c)(1 - p_2)\gamma = z_2.$$

In words, the type-2 leader only retains the market if it successfully innovates and there is no entry (i.e. with probability $z(1-p_2)$). If it does not innovate then its automatically upgraded type-3 rival catches up with it, and Bertrand competition between the two neck-and-neck firms dissipates all profits. If there is entry the entrant steals all the market.

- A state-1 leader, with $A_{t-1}(i) = \bar{A}_{t-1}$, chooses its innovative investment to:

$$\max_z \{\delta\left[z\bar{A}_t + (1-z)(1-p_1)\bar{A}_{t-1}\right] - c\left(z^2/2\right)\bar{A}_{t-1}\}.$$

Hence, from the first order condition we get:

$$z = (\delta/c)(\gamma - 1 + p_1) = z_1.$$

In words, the type-1 leader retains the market when: (i) it successfully innovates or (ii) it does not successfully innovate and there is no entry.

1.4 The "escape entry" and "discouragement" effects

Now consider the effects of increasing entry threat on innovative activity, which we here model as a reduction in the entry cost parameter Λ. In state-3 sectors an increase in the entry threat has no effect on innovation investments, since those are always equal to zero. Now, consider what happens in state-2 and state-1 sectors:

- In state-2 sectors, a reduction in Λ that increases the entry threat $p_2(\Lambda)$, reduces the expected payoff from innovating and therefore "discourages" innovation. Firms further behind the frontier know that they cannot survive entry, even if they successfully innovate. That is:

$$\frac{\partial z_2}{\partial \Lambda} = -(\delta/c)\gamma p_2'(\Lambda) > 0. \tag{6}$$

This *discouragement effect* is similar to the Schumpeterian appropriability effect of product market competition pointed out, for example, in Aghion et al. (2001, 2005a).

- In state-1 sectors, a reduction in Λ that increases the entry threat $p_1(\Lambda)$, fosters innovation as it increases the incumbent leaders' losses from entry if they do not innovate, thereby increasing their incentive to "escape entry" by innovating. That is:

$$\frac{\partial z_1}{\partial \Lambda} = (\delta/c)\, p_1'(\Lambda) < 0. \tag{7}$$

This *escape-entry effect* is similar to the escape-competition effect pointed out in Aghion et al. (2001, 2005a).

Together with the fact that laggards never innovate, this implies that an increase in the threat of entry discourages innovation in a state-2 sector and encourages it in a state-1 sector. Expected incumbent productivity growth in either sector is proportional to innovative investment:

$$E\left[\left(\frac{A_t\,(i) - A_{t-1}\,(i)}{A_{t-1}\,(i)}\right) | A_{t-1}(i) = \overline{A}_{t-j}\right] = z_j(\gamma - 1) = g_j,\ \ j \in \{1, 2\}. \tag{8}$$

Therefore a reduction in entry cost Λ has a positive escape-entry effect on incumbent productivity growth in state-1 sectors, and a negative discouragement effect in state-2 sectors:[5]

$$\frac{dg_1}{d\Lambda} = \frac{dz_1}{d\Lambda}(\gamma - 1) < 0; \qquad \frac{dg_2}{d\Lambda} = \frac{dz_2}{d\Lambda}(\gamma - 1) > 0.$$

1.5 Empirical implications

In summary, the main empirical implications that we draw from the theory are:

- *Increasing the threat of entry has a positive effect on incumbent innovation in sectors that are close to the technological frontier and a possibly negative effect in sectors that are further behind the frontier.*

[5] In state-3 sectors an increased entry threat does not affect the rate of productivity growth. Being upgraded with probability one, both firms in such sectors grow at the same constant rate $\gamma - 1$. Thus:

$$g_3 = \gamma - 1,$$

and a reduction in entry cost Λ has no effect on productivity growth.

- *Increasing the threat of entry has a more positive effect on incumbent productivity growth in sectors that are closer to the technological frontier than in sectors that are further behind the frontier.*

1.6 Linking entry threat and actual entry

The actual rate of entry in state-2 sectors is

$$E_2 = p_2(\Lambda), \tag{9}$$

since potential entrants can never lose against a type-2 incumbent. Thus, entry threat and actual entry are the same, and therefore the comparative statics of innovation as a function of entry threat also leads to the unambiguous prediction of a negative correlation between innovation by type-2 incumbents and actual entry in state-2 sectors.

The actual entry rate in state-1 sectors is

$$E_1 = p_1(1 - z_1), \tag{10}$$

so that the relationship between entry threat and actual entry in state-1 sectors is a priori ambiguous: a higher entry threat induces more innovative activity by type-1 incumbents in order to prevent entry, thereby counteracting the positive direct effect of entry threat on actual entry. However, the overall effect of entry threat on actual entry is positive, i.e. the effect of the entry cost parameter Λ on actual entry is negative, when Λ is not too small relative to the profit rate δ and the inverse of the R&D cost parameter c. We have

$$\frac{\partial E_1}{\partial \Lambda} = (1 - \frac{1}{c}\delta(\gamma - 1) - 2\frac{1}{c}\delta p_1(\Lambda))p_1'(\Lambda),$$

that is negative if and only if

$$p_1(\Lambda) < \frac{1 - \delta(\gamma - 1)/c}{2\delta/c}.$$

This holds if

$$\Lambda > \delta^2/c.$$

1.7 The level effect of the distance to the frontier

The theoretical model we rely on predicts a positive effect of the initial distance to frontier on innovation rates and expected productivity growth as is to be expected in any model where sectors converge to the same expected growth rates. We can show that if there is no threat of entry then the expected incumbent performance in a sector would be greater the further the sector is from the frontier (i.e. the level effect of the distance to the frontier would be positive). Assume for a moment that $p_1 = p_2 = 0$. Then the innovation rates in the different types of sectors become:

$$z_1 = (\delta/c)(\gamma - 1) < z_2 = (\delta/c)\gamma < 1$$

from which we obtain:[6]

$$g_1 = z_1(\gamma - 1) < g_2 = z_2(\gamma - 1) < g_3 = (\gamma - 1).$$

The economic reason for the result is twofold. First, expected growth in a sector three steps behind the frontier is higher than in a sector two steps behind because the former sector upgrades with probability one. Second, when there is no entry threat then a sector that is two steps behind is expected to grow faster than a sector just one step behind, because if the leader of the state-2 sector does not innovate then its rival, who is three steps behind the frontier, will catch up with him and the leader will earn no profits, whereas if the leader in a state-1 sector fails to innovate it will still remain one step ahead of its rival and hence will still earn positive profits; accordingly, the escape competition effect will give the leader in a state-2 sector a greater incentive to innovate than the leader of a state-1 sector.

1.8 Steady-state distribution of sectors and average incumbent productivity growth

Here we derive the steady-state fractions of all sectors j and show that increased threat of entry has a positive effect on the average rate of productivity growth among active incumbent

[6] See footnote 5 for the derivation of g_3.

firms across all sectors of the economy for plausible values of the R&D cost parameter c, frontier growth rate γ, entry cost parameter Λ and the additional cost term η. The latter cost term arises for an entrant that brings up to frontier level a sector that was initially further below the frontier. Let q_j denote the steady-state fraction of sectors in state j and $\bar{A}_{t-j}$ the productivity in such sectors at the beginning of period t. In steady state, the net flow of sectors into each technological state $j \in \{1, 2, 3\}$ must equal the net flow out of that state. More formally, if p_j denotes the entry threat into a type-j sector, we have:

$$p_2 q_2 + p_3 q_3 = (1 - p_1)(1 - z_1) q_1; \tag{11}$$

$$(1 - p_1)(1 - z_1) q_1 = [p_2 + (1 - p_2)(1 - z_2)] q_2; \tag{12}$$

$$(1 - p_2)(1 - z_2) q_2 = p_3 q_3; \tag{13}$$

plus the normalization

$$q_1 + q_2 + q_3 = 1. \tag{14}$$

The left hand sides (right hand sides) of (11), (12) and (13) correspond to the net flows into (out of) states 1, 2 and 3, respectively. Only three of the above four equations are linearly independent, and thus can be used to solve for q_1, q_2, q_3. Then, if g denotes the average productivity growth rate among active incumbent firms, we have:

$$g = q_1 g_1 + q_2 g_2 + q_3 g_3.$$

We want to know how this growth rate is impacted by an increase in the entry cost parameter Λ in the short run; that is, holding constant the probabilities q_i defining the distribution of initial technology gaps.

We can establish the following:

Proposition: *For η, γ and Λ sufficiently small, if $\delta < c$ then:*

$$\left.\frac{dg}{d\Lambda}\right|_{q=const} \equiv q_1 \frac{dg_1}{d\Lambda} + q_2 \frac{dg_2}{d\Lambda} + q_3 \frac{dg_3}{d\Lambda} < 0.$$

Proof: Since g_3 is independent of Λ, we have:

$$\left.\frac{dg}{d\Lambda}\right|_{q=const} = q_1\frac{dg_1}{d\Lambda} + q_2\frac{dg_2}{d\Lambda} = (\gamma-1)(q_1\frac{dz_1}{d\Lambda} + q_2\frac{dz_2}{d\Lambda}),$$

where we have made use of equation (8) in the text. Let

$$u = \delta/c \ \text{ and } \ \phi = \Lambda/\delta.$$

Now if we can prove the proposition for $\eta = 0$, by continuity it will also hold for η small. Thus, let us fix η at zero. Using (3) and (5) we can then reexpress the probabilities of entry as:

$$p_1(\phi) = \frac{1-u(\gamma-1)}{\phi+u} \text{ and } p_2(\phi) = p_3(\phi) = 1/\phi. \tag{15}$$

We can use (15) to reexpress the equilibrium innovation rates z_1 and z_2 respectively as:

$$\left\{\begin{array}{l} z_1(\phi) = u(p_1(\phi) + \gamma - 1) \\ z_2(\phi) = u(1 - p_2(\phi))\gamma \end{array}\right\} \tag{16}$$

Next, using the steady-state equations (11) $\sim$ (14), we get:

$$\left\{\begin{array}{l} q_1(\phi) = \frac{p_2(\phi)}{p_2(\phi)+(1-p_1(\phi))(1-z_1(\phi))} \\ q_2(\phi) = \frac{q_1(\phi)(1-p_1(\phi))(1-z_1(\phi))}{p_2(\phi)+(1-p_2(\phi))(1-z_2(\phi))} \end{array}\right\} \tag{17}$$

So, we have:

$$\begin{aligned} \left.\frac{dg}{d\Lambda}\right|_{q=const} &= (\gamma-1)\left(q_1(\phi)\,\delta z_1'(\phi) + q_2(\phi)\,\delta z_2'(\phi)\right) \\ &\sim \left(z_1'(\phi) + \frac{q_2(\phi)}{q_1(\phi)} z_2'(\phi)\right) \\ &\sim \left(p_1'(\phi) - \frac{(1-p_1(\phi))(1-z_1(\phi))}{p_2(\phi)+(1-p_2(\phi))(1-z_2(\phi))}\gamma p_2'(\phi)\right) \\ &= \left(-\frac{1-u(\gamma-1)}{(\phi+u)^2} + \frac{(1-p_1(\phi))(1-z_1(\phi))}{p_2(\phi)+(1-p_2(\phi))(1-z_2(\phi))}\gamma\frac{1}{\phi^2}\right) \end{aligned}$$

Clearly ϕ and γ have a lower limit of unity. (If $\phi < 1$ then $p_2 = p_3 > 1$, which makes no sense.) As we approach the limiting case where $\phi = \gamma = 1$ then, from (15) $\sim$ (17), we have:

$$p_1(\phi) \to \frac{1}{1+u},\ p_2(\phi) \to 1,\ z_1(\phi) \to \frac{u}{1+u} \text{ and } z_2(\phi) \to 0$$

Substituting these into the final expression above for $\frac{dg}{d\Lambda}\Big|_{q=const}$, we have in the limit:

$$\frac{dg}{d\Lambda}\Bigg|_{q=const} \sim \left(-\frac{1-u}{(1+u)^2}\right)$$

in which the right-hand side is negative when $\delta < c$ because then $u < 1$. $\|$

2 Data and descriptive statistics

2.1 Data sources

Plant and establishment level data for the manufacturing sector come from the U.K. Office for National Statistics (ONS) Annual Respondents Database (ARD).[7] Data on ownership, four-digit SIC 1980 industry classification, and employment is collected for the *population of plants located in the United Kingdom*. Panel data on inputs and outputs are available for a *random stratified sample of establishments* selected for a detailed annual survey.[8] The data for all of Great Britain, i.e. U.K. excluding Northern Ireland, is accessible to us.

The establishment survey is conducted by the ONS under the 1947 Statistical Trade Act. This makes it a legal obligation for firms to report and thus there is effectively no bias from non-random survey response. Establishments with more than 100 employees are all selected for the survey in the years relevant to us, as well as a stratified random sample of smaller units.[9] In our main empirical analyzes we weight observations by the inverse of their sampling probability and employment to control for the sampling scheme and the fact that measurement error may be larger in smaller establishments. In table A.5, columns 1 to 6, we show that our estimation results are robust to using non-weighted data.

The plant and establishment data in the ARD covers ownership information that is updated annually from Dun & Bradstreet's "Who Own's Whom" database. The nationality of a plant or establishment is determined by the country of residence of its global ultimate owner.

Due to our focus on reactions to entry in incumbents we restrict our estimation sample to observations on incumbent establishments that are domestic-owned between 1986 and 1993

[7] See Barnes and Martin (2002), Griffith (1999) and Oulton (1997) for further information.

[8] An establishment represents a line of business in a firm and production decisions are most likely to be made at that level. About 77 percent of all British establishments that are sampled between 1980 and 1993 are single plants, i.e. sites located at a single mailing address. On average, an establishment represents 1.6 plants that operate in the same four-digit industry and are owned by the same firm. A firm can own more than one establishment per four-digit industry.

[9] The sample selected for the survey accounts for about 90 percent of annual total U.K. manufacturing employment according to Oulton (1997).

and (i) at least 5 years old and/or (ii) had more than 100 employees in at least one year between 1986 and 1993.[10] We drop all observations before 1987 and after 1993 since reliable entry measures are not available to us for the mid 1980s and mid 1990s due to major changes in data collection. We also apply the following standard data cleaning routines. We exclude all establishments not yet producing or under public ownership. We drop observations with missing or negative key variables (output, value added, intermediate inputs, employment, capital stock), observations where absolute growth in these key variables is over 150 percent, observations with missing values for any variable used in our regression analyzes and observations with extreme values of the productivity growth, entry rate or distance to frontier distributions. We eliminate establishments that were observed for less than three consecutive years between 1987 and 1993. The resulting sample consists of 25,388 observations on 5,161 domestic incumbent establishments in 180 four-digit SIC 1980 industries. Descriptive statistics are provided in table A.1.

The **firm level data** on patenting activity that we use includes patent information from the NBER/Case Western Patent database with over two million patents granted by the U.S. Patent Office between 1901 and 1999. This patent data is linked to a panel of firms for which accounting data from DataStream are available. The sample covers 415 firms that are publicly listed on the London Stock Exchange (LSE) in 1985, have names starting with the letters A-L and/or are among the top 100 U.K. R&D spenders. Subsidiaries of these firms were identified using "Who owns Whom" by Dun and Bradstreet in 1985 (or in the year of sample entry in case a firm enters the sample after 1985) and all entities were matched by name to the NBER/Case Western Patent database.[11]

All firms in the database can be considered incumbent since firms listed at the LSE are typically reasonably old and large. We exclude accounting periods of less (more) than

[10] We find similar empirical results when imposing both (i) *and* (ii) or using another sub-sample of firms that are particularly prone to take a position as incumbent industry leader. See table A.3, columns 1 and 2 for details.

[11] See Bloom and Van Reenen (2002) for further information.

330 (400) days. We drop observations with missing or implausible capital stock values, missing values of employment or sales, observations where absolute growth of these three key variables exceeds 150 percent, observations with missing values for any variable used in our regression analyzes and observations with extreme values of the entry rate or distance to frontier distributions. We focus on manufacturing firms with at least three consecutive observations in the time period 1987 to 1993. This leaves us with an estimation sample of 1,073 observations on 174 firms in 60 three-digit SIC 1980 industries described in greater detail in table A.1.

We use **industry level data** from three sources. Most of our U.K. industry data is aggregated from the plant or establishment panel data in the ARD.[12] Most of our U.S. industry information comes from the NBER manufacturing productivity database (MPD).[13] To connect the U.S. MPD to the U.K. ARD we match four-digit industries from the U.K. SIC 1980 industry code to the corresponding four-digit industries in the U.S. SIC 1987 code.[14] Since our panel of LSE-listed firms informs about three-digit industry codes only we conduct a similar matching on the three-digit industry level. In addition to industry data from the ARD or MPD, we use 2-digit industry data from the OECD STAN database.

2.2 Variables

Productivity growth: To calculate productivity growth we use disaggregated information from the ARD on gross output, capital expenditures, intermediate inputs, the number of skilled workers (administrative, technical and clerical workers) and unskilled workers (operatives) as well as their respective wage bills, all in nominal terms. To deflate output and intermediate input measures we have ONS price deflators for output and intermediate goods

[12]Before calculating industry-level variables we apply basic data cleaning routines to the raw plant and establishment data in the ARD.

[13]See Bartelsman and Gray (1996) for details.

[14]Of all 205 four-digit U.K. industries that we wanted to match 146 could be linked exclusively to one or several U.S. four-digit industries. 50 U.K. industries could be successfully linked to U.S. industries after having formed U.K. industry pairs and three larger U.K. industry groups. Nine remaining U.K. industries could not be linked to an industry in the U.S. manufacturing sector.

at the four-digit industry level. A price index at the 2-digit industry level is available for investment in plant and machinery. The price index for investment in building and land is at the aggregate level, as is the one for investment in vehicles. Wages are deflated using the U.K. Retail Price Index. Our base year for deflation is 1980. Capital stock data is constructed from investment series using the perpetual inventory method. Estimation of initial capital stock values involves using establishment-level energy input and industry-level capital stock data.

Growth of labor productivity ($\triangle LP_{ijt}$) is defined as:

$$\triangle LP_{ijt} = \triangle \ln Y_{ijt} - \triangle \ln L_{ijt}, \tag{18}$$

where Y denotes real gross output and L the number of employees in establishment i in industry j at time t.

We use a superlative index number approach to calculate **growth of total factor productivity ($\triangle TFP_{ijt}$)**:[15]

$$\triangle TFP_{ijt} = \triangle \ln Y_{ijt} - \sum_{z=1}^{Z} \tilde{\alpha}_{ijt}^{z} \triangle \ln x_{ijt}^{z}, \tag{19}$$

where Y denotes real gross output, Z the number of factors of production, and x_{ijt}^{z} the quantity of factor z that is used in establishment i in industry j at time t in real terms. We consider four factors of production: skilled labor, unskilled labor, the stock of physical capital, and intermediate inputs. The standard superlative index number approach as we apply it builds on a flexible translog production function, imposing constant returns to scale ($\sum_z \tilde{\alpha}_{ijt}^{z} = 1$) and perfect product market competition.

Superlative index number measures of TFP growth that do not rely on the assumption of perfect product market competition can be calculated along the lines of Hall (1988), Roeger

[15] See Caves et al. (1982a, b) among others.

(1995) or Klette (1999). We find our empirical results to be robust to relaxing the assumption of perfect product market competition (table A.3, column 5).

Factor shares $\tilde{\alpha}^z_{ijt}$ are defined as $\tilde{\alpha}^z_{ijt} = (\alpha^z_{ijt} + \alpha^z_{ijt-1})/2$ with α^z_{ijt} denoting the cost of factor z relative to the value of total output in establishment i in industry j at time t. Since observed factor shares α^z_{ijt} can be noisy and may exceed one we apply a smoothing procedure proposed by Harrigan (1997). Assuming a translog production technology, constant returns to scale (CRS), and standard market-clearing conditions, α^z_{ijt} can be expressed as follows:[16]

$$\alpha^z_{ijt} = \psi_i + \varphi_{jt} + \sum_{z=2}^{Z} \omega^z_j \ln\left(\frac{x^z_{ijt}}{x^1_{ijt}}\right), \tag{20}$$

where ω^z_j are coefficients of relative factor input use that are allowed to vary across four-digit industries. Normalization is relative to production factor 1 to impose CRS. We also allow for industry-specific time effects φ_{jt} and for establishment-specific effects ψ_i. If observed factor shares deviate from their true values by an i.i.d. measurement error term, then this equation can be estimated by running separate regressions for each four-digit industry j.[17] The fitted values from (20) are used as factor shares in the calculation of (19). We find our estimation results to be robust if we do not use the above smoothing procedure and estimate on those establishment observations only where the sum of observed factor shares is between zero and one (table A.3, column 6).

Innovation: The panel of firms listed at LSE provides us with the count of patents firms take out in the U.S. Patent Office. Using an innovation measure that focuses on U.S. patents of U.K. firms is advantageous in our context, since U.K. firms are unlikely to patent low value inventions in the United States.

Entry: We measure greenfield firm entry into U.K. industries using the ARD panel data on the population of manufacturing plants in Great Britain. Time-varying ownership data allows for distinguishing between entry from foreign and domestic firms.[18]

[16] See Caves et al. (1982b) and Harrigan (1997).

[17] Since this procedure does not allow for factor share smoothing in very small industries we do not calculate growth of TFP for four-digit industries with less than 10 establishments between 1980 and 1993.

[18] As firms we term establishment groups in the ARD.

Our main measure for technologically advanced entry is the greenfield foreign firm entry rate. We define it as follows:

$$E_{jt} = \frac{\sum_{i=1}^{N_{jt}} L_{ijt} * D_{ijt}(greenfield\ site;\ owner = foreign,\ new\ in\ j\ in\ t)}{\sum_{i=1}^{N_{jt}} L_{ijt}} * 100, \qquad (21)$$

where N_{jt} is the number of all production sites, i.e. plants, in industry j in year t and L_{ijt} is the number of employees in plant i in industry j and year t. The function $D_{ijt}\,(.)$ equals one if a foreign-owned firm enters industry j in Great Britain with a new *greenfield* production site in year t *and* did *not* already own sites in the respective British industry in previous years, otherwise $D_{ijt}\,(.)$ equals zero.[19] The denominator is the number of employees in all production sites in industry j at time t.[20]

For the productivity growth models we measure entry at the four-digit industry level. For the patent count models we measure entry at the three-digit level since our panel of LSE-listed firms provides industry information on the three-digit industry level only.

Greenfield domestic firm entry that we use to proxy entry further behind the technology frontier is calculated in a similar manner. The value range for our entry measures is 0 to 100.

Distance to the technology frontier: We measure the distance of incumbents in each U.K. industry to its U.S. industry counterpart using data on U.S. industries from the NBER MPD and U.K. data aggregated up from the ARD.[21] Our preferred measure is the following labor productivity ratio:

$$D_{jt} = \frac{1}{3}\sum_{z=0}^{2}(\ln \frac{Y_{jt-z}^{US}}{L_{jt-z}^{US}} - \ln \frac{Y_{jt-z}^{UK}}{L_{jt-z}^{UK}}) \qquad (22)$$

[19] If a foreign firm enters industry j simultaneously with more than one plant in year t then the initial employment in all these plants is counted.

[20] Note that the ARD covers plants that enter and exit in the same year (Disney et al. 2003). All entry measures we use in the paper are qualified measures in the sense of ignoring these transitory one-year units. However, we find similar results when experimenting with measures that include these one-year units.

[21] The microdata underlying the NBER MPD and the ARD are collected by national statistical agencies using similar methods.

where Y_{jt-z}^{US} denotes real value added in U.S. industry j in year $t-z$, L_{jt-z}^{US} denotes the corresponding number of employees, and UK indicates the U.K. industry variables. The definitions of value added and the number of employees are similar across the involved U.S. and U.K. databases. We calculate a three year moving average over the years t to $t-2$ to mitigate the effects of measurement error on the time variation of the distance variable. In doing so we include input and output data for the presample period before 1987.

For estimating productivity growth models we use a disaggregated distance measure that compares incumbent four-digit U.K. industries to matched four-digit U.S. industries.[22] For the patent count models we calculate the respective measure on the three-digit industry level.

To check for robustness of our empirical results when switching from labor productivity to an alternative technology metric we also use a superlative index number measure that relates TFP in each incumbent U.K. industry to its corresponding U.S. industry equivalent. In addition to moving averages, we do also consider discretized distance to frontier measures to address concerns about measurement error. These indicators group industries above and below the median of the respective continuous distance variables. See table A.3, column 7 for results.

Import penetration: We calculate the share of the value of imports over the value of domestic output using 2-digit industry level panel data from the OECD STAN database.

Competition: Our preferred measure for variation in competitive conditions is an index of average profitability based on ARD panel data. The profitability measure is output minus labor, intermediate good and capital costs divided by output for each establishment and the index is defined as 1 minus the market share-weighted average of the profitability measure across all incumbent establishments in the industry. The index takes values between 0 and 1 and a value of 1 indicates perfect competition.[23]

[22] See section 2.1 on the industry code matching.

[23] Experimenting with an unweighted average or different weighting schemes had only negligible effects

Patent stock variables: The panel of firms listed at LSE provides presample patent information that we use to construct a measure of the firm-specific **patent stock** built up between 1968 and the beginning of the first year the firm is in our estimation sample, i.e. 1987 in most cases. We apply the perpetual inventory method and calculate the stock measure as the sum of all presample patents depreciated to the last year of the presample period using an annual knowledge depreciation rate of 30 percent.[24] In addition to the stock measure, we constructed an **indicator of the presample patenting activity** that is equal to one if the firm ever patented in the presample period.

Instrumental variables: To instrument entry we exploit variation coming from several major product market policy interventions: the EU Single Market Programme, the U.K. privatization programme and U.K. merger and monopoly cases. We use data on cases that were investigated by the U.K. Competition Autority and where remedial actions were recommended and undertaken. See table A.4 for details on the policy interventions. In extended model specifications we also allow for endogeneity of the distance to the technology frontier and use the capital-labor ratio and the share of skilled workers in U.S. four-digit industries as additional instruments. When dealing with potential endogeneity in import penetration or competition we add as instruments U.S. import penetration on the 2-digit level or an index of average profitability in U.S. four-digit industries, respectively.

on the estimated effects of entry, distance to frontier and interaction terms. Using a market share measure instead of a profitability-based competition measure also gave similar results.

[24] We find our empirical results to be insensitive to the chosen depreciation rate when experimenting with other rates between 15 and 45 percent.

Table A.1: Descriptive statistics

Variable	Mean	Median	Standard deviation
ARD sample of establishments			
Growth of labor productivity$_{ijt}$	0.011	0.011	0.138
Growth of total factor productivity$_{ijt}$	-0.010	-0.007	0.118
Foreign firm entry rate (in %)$_{jt-1}$	0.131	0	0.484
Number of employees in new foreign firms (in 1000)$_{jt-1}$	0.055	0	0.242
Number of employees (in 1000)$_{jt-1}$	40.924	31.381	32.264
Distance to the frontier$_{jt-1}$, labor productivity-based	0.208	0.200	0.281
Distance to the frontier$_{jt-1}$, TFP-based	0.090	0.101	0.139
Import penetration$_{jt-1}$	0.951	0.905	0.452
Competition$_{jt-1}$	0.898	0.909	0.063
Domestic firm entry rate (in %)$_{jt-1}$	2.470	1.997	1.840
Establishment size (in 1000)$_{jt-1}$	0.387	0.309	0.266
Working owner share$_{jt-1}$	0.015	0.005	0.030
Capital-labor ratio (real, in million £ per employee)$_{jt-1}$	0.018	0.014	0.022
EU Single Market Program$_{jt-1}$	0.317	0	0.465
U.K. Privatization$_{jt-1}$	0.043	0	0.246
U.K. Merger cases$_{jt-1}$	0.020	0	0.149
U.K. Monopoly cases$_{jt-1}$	0.083	0	0.443
U.S. Capital-labor ratio (real, in million £ per employee)$_{jt-1}$	0.037	0.029	0.032
U.S. Skilled worker share$_{jt-1}$	0.286	0.243	0.136
U.S. Import penetration$_{jt-1}$	0.419	0.320	0.262
U.S. Competition$_{jt-1}$	0.743	0.750	0.087
Sample of firms listed at LSE			
Number of U.S.-patents$_{ijt}$	7.968	0	24.181
Patent stock$_{i,\ presample}$	24.114	1.375	81.180
D(patent stock$_{i,\ presample}$>0)	0.664	1	0.472
Foreign firm entry rate (in %)$_{jt-1}$	0.165	0.028	0.425
Number of employees in new foreign firms (in 1000)$_{jt-1}$	0.156	0.021	0.371
Number of employees (in 1000)$_{jt-1}$	92.492	59.868	76.277
Distance to the frontier$_{jt-1}$, labor productivity-based	0.205	0.221	0.278
Distance to the frontier$_{jt-1}$, TFP-based	0.080	0.105	0.148
Import penetration$_{jt-1}$	1.035	1.088	0.466
Competition$_{jt-1}$	0.891	0.903	0.056
Domestic firm entry rate (in %)$_{jt-1}$	2.227	1.884	1.499
Establishment size (in 1000)$_{jt-1}$	0.495	0.378	0.405
Working owner share$_{jt-1}$	0.014	0.008	0.027
Capital-labor ratio (real, in million £ per employee)$_{jt-1}$	0.019	0.015	0.017
EU Single Market Program$_{jt-1}$	0.397	0	0.490
U.K. Privatization$_{jt-1}$	0.117	0	0.331
U.K. Merger cases$_{jt-1}$	0.069	0	0.257
U.K. Monopoly cases$_{jt-1}$	0.289	0	0.820
U.S. Capital-labor ratio (real, in million £ per employee)$_{jt-1}$	0.040	0.031	0.034
U.S. Skilled worker share$_{jt-1}$	0.328	0.308	0.135
U.S. Import penetration$_{jt-1}$	0.477	0.504	0.250
U.S. Competition$_{jt-1}$	0.728	0.737	0.083

Notes: The table provides non-weighted descriptive statistics for all main variables in the ARD sample of 25,388 observations on 5,161 domestic incumbent establishments between 1987 and 1993 and in the sample of 1,073 observations on 174 firms listed at the LSE in the time period 1987 to 1993. Import penetration is measured at the 2-digit level. All other industry variables used in connection with the ARD sample are measured at the four-digit industry level, those used in connection with the firm sample at the three-digit level. All distance to frontier measures and their instruments, i.e. the U.S. capital-labor ratio and the U.S. skilled worker share, are lagged moving averages that average over the three preceding years. All other lagged variables are lagged by one year.

Table A.2: Sample variation of the industry-specific distance to the technology frontier

SIC-80 code	Industry description	Distance to frontier
Large industries close to the frontier (≤ median distance to frontier)		
4671	wooden and upholstered furniture	0.049
4310	woolen and worsted industry	0.084
4510	Footwear	0.111
4751	printing and publishing of newspapers	0.214
4536	woman's and girl's light outerwear, lingerie and infants' wear	0.290
4363	hosiery and other weft knitted goods and fabrics	0.316
3443	radio and electronic capital goods	0.362
4725	packaging products of boards	0.367
4130	preparation of milk and milk products	0.404
3284	refrigerating, space heating and ventilating equipment	0.414
Large industries further behind the frontier (> median distance to frontier)		
3120	forging, pressing and stamping	0.480
3710	measuring, checking and precision instruments	0.514
3420	basic electrical equipment	0.518
3640	aerospace equipment manufacturing and repairing	0.519
2570	pharmaceutical products	0.585
4196	bread and flour confectionery	0.664
2512	basic organic chemicals except specialized pharmaceutical chemicals	0.732
4122	bacon curing and meat processing	0.893
3530	motor vehicle parts	0.945
4214	cocoa, chocolate and sugar confectionery	0.989

Notes: In this table we illustrate how the industry-specific distance to the technology frontier varies across the sample. Large U.K. four-digit industries in the group of industries close to the technology frontier, i.e. below the median distance to frontier, are listed in the upper panel, large industries further behind in the lower one. All industries shown have more than 30,000 employees in 1987. Distance to frontier is measured by the labor productivity distance of U.K. four-digit industries relative to their industry-specific U.S. counterparts between 1984 and 1986. Calculations are based on the estimation sample for productivity growth models.

Table A.3: Entry at different distances to the technology frontier

	Quartiles of the distance to frontier distribution			
	1 (close)	2	3	4 (far)
	mean (standard deviation)			
# employees in entering foreign firms	32 (226)	34 (104)	33 (149)	34 (169)
foreign entry rate in %	0.10 (0.43)	0.13 (0.40)	0.13 (0.47)	0.12 (0.54)
# entering employees if foreign entry > 0	158 (481)	121 (168)	102 (251)	188 (363)
foreign entry rate in % if foreign entry > 0	0.48 (0.85)	0.46 (0.65)	0.40 (0.76)	0.66 (1.13)
foreign entrants size	75 (236)	61 (96)	59 (160)	97 (238)

Notes: In this table we describe how foreign firm entry between 1986 and 1992 varies with the labor productivity distance of U.K. four-digit industries relative to their industry-specific U.S. counterparts. Calculations are based on the estimation sample for productivity growth models.

Table A.4: Description of product market policy interventions

EU Single Market Program (SMP)	Year
The aims of the SMP were to bring down EU internal barriers to the free movement of goods, services, capital and labor by interventions like harmonizing product standards, indirect taxes and border controls, removing national requirements and other non-tariff barriers that enable firms to segment markets and limit competition, restricting public sector discrimination in favor of its own firms, and reducing capital as well as labor costs by permitting free flow across countries. We use 1988 as the date of the SMP intervention, rather than the "official" implementation date of 1992. We do so, because information about how specific industries would be affected by the SMP became available earlier, especially in the 1988 Cecchini-Report to the EU. 41 three-digit industries were ex ante expected to be strongly or moderately affected (Mayes and Hart, 1994).[1]	1988

U.K. Privatization cases	Year	Industry code (SIC 80)
The U.K. privatization program undertaken by the Thatcher government was a large scale intervention that led to the sale of a substantial portion of government owned assets.[2] The U.K. program took place earlier than similar programs in other countries and so many privatization decisions have not been anticipated to the extend they were in other countries. Most interventions resulted in opening up directly affected and related markets to entry of new firms. For each directly affected industry we use the years of the respective stock market sales as intervention dates.		
Ordnance, small arms and ammunition: Royal Ordnance	1987	3290
Car parts: Unipart	1987	3530
Aerospace equipment manufacturing: Rolls Royce	1987	3640
Motor vehicles and engines: Leyland Bus, Leyland Truck, Freight Rover, Rover Group.	1987, 1988	3510
Shipbuilding: British Shipbuilders	1987, 1988, 1989	3610
Iron and steel industry: British Steel	1988	2210
Telecommunication equipment: British Telecom	1991	3441

[1] The term SMP itself can be traced back to a European Commission's White Paper of 1985 (EC, 1985).

[2] See, for example, PriceWaterhouseCoopers (1998) and Megginson and Netter (2001).

U.K. Merger and monopoly cases

The U.K. Competition Authority (currently the Competition Commission, before 1999 the Monopolies and Mergers Commission) has responsibility for undertaking case-by-case investigations of potential mergers or potential monopoly situations in order to determine whether the merger or actions of firms in the industry are, or can be expected, to operate against the public interest by distorting competition, preventing entry, increasing prices or reducing consumers' choice. Where the Commissioners conclude that this is the case they can recommend remedial interventions such as prohibitions or divestments.

We use information on those cases where remedial actions were recommended and undertaken.[3] As intervention date we use the year a respective merger or monopoly case was *referred* to the Competition Authority. This is the date on which it is first publicly announced that an inquiry will take place. Decisions are generally undertaken within a year (though longer in some complex cases) and reforms can take longer.

	Year	Industry code (SIC 80)
Opium derivatives	1987, 1988	2570
Advertising in rambling magazines	1987, 1988, 1989	4751
Roof trusses and connector plates	1988	3204
Medical and surgical equipment	1987	3720
Beer and brewing industry	1988, 1990, 1992	4270
Power tools, portable work benches	1989	3285
Defense equipment, electronics industry, telecommunications	1989	3433
Sewing thread and textile industry	1989	4321
Tires	1989	4811
Fertilizers	1990	2513
Organic pastes, oil-based muds, organoclays, paint	1990	2567
Razors and shaving equipment	1990	3162
Carbonated drinks and soft drinks	1990	4283
Matches, cigarette lighters, smokers requisites	1991	2565
Sugar	1991	4200
Wool, wool scouring, textile industry	1991	4310
Cross media promotion of publications	1991	4753
Shoe polish	1992	2599
Animal waste, Rendering, Meat	1992	4126
Dairy products and milk	1992	4130

[3] See http://www.competition-commission.gov.uk/ or http://www.mmc.gov.uk/ for published case reports. Davies et al. (1999) and Clarke et al. (1998) provide further analyses of these cases.

3 Additional empirical results

In this section we present additional empirical results in the following seven tables:

Table A.5: Entry and first stage equations – Additional specifications

Table A.6: Productivity growth – Reduced sets of covariates

Table A.7: Productivity growth – Alternative samples, entry-distance interactions, and TFP measures

Table A.8: Productivity growth – Alternative sets of instruments

Table A.9: Robustness results – Specifications as in table 2 using non-weighted data and as in table 4 with TFP growth as dependent variable

Table A.10: Robustness results – Specifications including distance-competition interactions or allowing for endogeneity of covariates

Table A.11: Robustness results – Expanded sets of covariates

Table A.5: Entry and first stage equations – Additional specifications

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS
Dependent variable	Foreign entry$_{jt-1}$	Foreign entry$_{jt-1}$	Foreign entry$_{jt-1}$ ×Distance$_{jt-1}$	Distance$_{jt-1}$	Foreign entry$_{jt-1}$	Foreign entry$_{jt-1}$ ×Distance$_{jt-1}$	Import penetration$_{jt-1}$
EU Single Market Program$_{jt-1}$(SMP)		**0.023**	**0.030**	**0.050**	**0.027**	**0.005**	**0.013**
		(0.014)	*(0.007)*	*(0.007)*	*(0.017)*	*(0.007)*	*(0.003)*
U.K. Privatization cases$_{jt-1}$ (P)		**0.220**	**0.056**	**-0.067**	**0.194**	**0.054**	**0.097**
		(0.028)	*(0.013)*	*(0.019)*	*(0.029)*	*(0.012)*	*(0.012)*
U.K. Merger cases$_{jt-1}$ (MM)		**0.115**	**0.012**	**0.040**	**0.126**	**0.004**	**0.012**
		(0.048)	*(0.011)*	*(0.010)*	*(0.049)*	*(0.013)*	*(0.005)*
U.K. Monopoly cases$_{jt-1}$ (MM)	**0.041**	**0.014**	**-0.022**	**0.095**	**0.034**	**-0.040**	**-0.016**
	(0.024)	*(0.103)*	*(0.044)*	*(0.034)*	*(0.102)*	*(0.050)*	*(0.011)*
U.S. capital-labor ratio$_{jt-1}$		**2.387**	**0.423**	**2.451**			
		(1.779)	*(1.118)*	*(0.769)*			
U.S. skilled worker share$_{jt-1}$		**-1.318**	**-0.353**	**-0.673**			
		(0.564)	*(0.237)*	*(0.218)*			
U.S. import penetration$_{jt-1}$					**0.006**	**0.330**	**1.023**
					(0.264)	*(0.107)*	*(0.041)*
Additional industry-specific reform controls	475	248, 2565, 3204, 361, 371, 432/438, 475	248, 2565, 3204, 361, 371, 432/438, 475	248, 2565, 3204, 361, 371, 432/438, 475	248, 2565, 3204, 361, 371, 432/438, 475	248, 2565, 3204, 361, 371, 432/438, 475	248, 2565, 3204, 361, 371, 432/438, 475
Distance & competition effects					Yes	Yes	Yes
Import & competition effects		Yes	Yes	Yes			
Year & establishment effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test, SMP variables		19.31(5)	27.35(5)	42.17(5)	20.00(5)	26.69(5)	21.26(5)
F-test, P variables		31.21(2)	10.25(2)	6.22(2)	24.25(2)	10.85(2)	66.90(2)
F-test, MM variables	90.40(2)	89.52(5)	76.42(5)	100.35(5)	92.03(5)	69.91(5)	13.44(5)
F-test, U.S. variables		2.91(2)	1.40(2)	9.35(2)	0.00(1)	9.41(1)	628.57(1)
F-test, all excluded instruments		46.39(14)	47.37(14)	166.23(14)	48.66(13)	42.80(13)	115.29(13)
Number of observations	25,388	25,388	25,388	25,388	25,388	25,388	25,388

Notes: The table shows OLS estimates of one basic entry model and of first stage equations for the sample of 25,388 observations on 5,161 domestic incumbent establishments between 1987 and 1993. See table 4 in the paper and table A.9 in this Web appendix for related second stage regressions. Bold numbers indicate coefficients. Standard errors in parentheses and italics are robust, and observations are weighted by employment and the inverse of their sampling probability. In rows with F-test statistics numerator degrees of freedom are in parentheses. The policy instruments that we use in the first stage equations shown here are the EU Single Market Program instruments and U.K. policy instruments as in columns 9 and 10 of table 1 in the paper. Industry-specific reform variables are used for the following SIC-80 industries: 248 (refractory and ceramics), 2565 (explosive chemical products), 3204 (fabricated constructional steel work), 361 (shipbuilding and repairing), 371 (precision instruments), 432/438 (cotton and silk, carpets and other textile floor coverings) and 475 (printing and publishing).

Table A.6: Productivity growth – Reduced sets of covariates

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS	(9) OLS	(10) OLS
Dependent variable	Growth of labor productivity$_{ijt}$					Growth of total factor productivity$_{ijt}$				
Employment in foreign entrants$_{jt-1}$	**0.019**					**0.017**				
	(0.004)					*(0.002)*				
Employment$_{jt-1}$	**0.0004**					**0.0003**				
	(0.0004)					*(0.0004)*				
Foreign entry rate$_{jt-1}$		**0.009**					**0.008**			
		(0.004)					*(0.003)*			
Distance to frontier$_{jt-1}$			**0.088**					**0.091**		
			(0.033)					*(0.020)*		
Import penetration$_{jt-1}$				**0.093**					**0.105**	
				(0.036)					*(0.036)*	
Competition$_{jt-1}$					**0.095**					**0.171**
					(0.053)					*(0.066)*
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Establishment effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	25,388	25,388	25,388	25,388	25,388	25,388	25,388	25,388	25,388	25,388

Notes: The table displays OLS estimates of productivity growth models with reduced sets of covariates for the sample of 25,388 observations on 5,161 domestic incumbent establishments between 1987 and 1993. The results are discussed in section 4.2 (IV.B) of the paper. Bold numbers indicate coefficients. Standard errors in parentheses and italics are robust and allow for correlation between establishments within the same industry. Observations are weighted by employment and the inverse of their sampling probability.

Table A.7: Productivity growth – Alternative samples, entry-distance interactions, and TFP measures

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS
	Sub-samples with establishments more likely to lead the industry		**Sub-samples with establishments more likely to lag behind**		**Alternative TFP measures**		**Alternative entry-distance interactions**
Dependent variable	Growth of labor productivity$_{ijt}$						
Foreign entry$_{jt-1}$×distance$_{jt-1}$(E^F×D^{LP})	**-0.050**	**-0.057**	**0.025**	**-0.026**			
	(0.010)	*(0.010)*	*(0.050)*	*(0.024)*			
Foreign entry, near TFP frontier$_{jt-1}$							**0.011**
							(0.005)
Foreign entry, far TFP frontier$_{jt-1}$							**0.006**
							(0.003)
Foreign entry$_{jt-1}$(E^F)	**0.020**	**0.019**	**0.0005**	**0.014**			
	(0.002)	*(0.002)*	*(0.012)*	*(0.007)*			
Distance to frontier$_{jt-1}$($D^{LP\ or\ TFP}$)	**0.093**	**0.121**	**-0.010**	**0.062**			**0.077**
	(0.033)	*(0.029)*	*(0.061)*	*(0.035)*			*(0.043)*
Controls as in table 2 of the paper	Yes	Yes	Yes	Yes			Yes
Dependent variable	Growth of total factor productivity$_{ijt}$						
Foreign entry$_{jt-1}$×distance$_{jt-1}$(E^F×D^{LP})	**-0.058**	**-0.058**	**-0.020**	**-0.037**	**-0.049**	**-0.047**	
	(0.014)	*(0.013)*	*(0.019)*	*(0.022)*	*(0.025)*	*(0.015)*	
Foreign entry, near TFP frontier$_{jt-1}$							**0.010**
							(0.005)
Foreign entry, far TFP frontier$_{jt-1}$							**0.005**
							(0.004)
Foreign entry$_{jt-1}$(E^F)	**0.021**	**0.018**	**0.011**	**0.016**	**0.021**	**0.017**	
	(0.003)	*(0.003)*	*(0.005)*	*(0.006)*	*(0.006)*	*(0.004)*	
Distance to frontier$_{jt-1}$($D^{LP\ or\ TFP}$)	**0.093**	**0.092**	**0.044**	**0.090**	**0.055**	**0.075**	**0.103**
	(0.021)	*(0.027)*	*(0.041)*	*(0.026)*	*(0.038)*	*(0.020)*	*(0.031)*
Controls as in table 2 of the paper	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	20,098	12,989	5,290	12,399	25,388	21,984	25,388

Notes: In col. 1-4 we show how our findings vary across sub-samples. We use a) sub-samples of firms that are *more* likely to take a position as industry leader: in col. 1 establishments that are domestic-owned and (i) at least 5 years old *and* (ii) have more than 100 employees under domestic ownership at least once between 1986 and 1993; in col. 2 establishments that are *above or at* the median TFP level in the industry-year specific distribution of the lagged TFP level; and b) sub-samples of firms that are *less* likely to take a position as industry leader: in col. 3 establishments that fulfill one of the conditions (i) or (ii) mentioned in a), but not the other; in col. 4 establishments that are *below* the median TFP level in the industry-year specific distribution of the lagged TFP level. A discussion of these results can be found in section 3.2 (III.B) of the paper.

In col. 5 we use a TFP growth measure allowing for imperfect competition and in col. 6 we use a TFP growth measure that involves no use of a factor share smoothing procedure. See section 2 in this Web appendix on TFP measurement and result discussion. In col. 7 we use a TFP-based distance to frontier measure and two interaction terms. One is the interaction of foreign entry and an indicator for industries above the year-specific median of the TFP-based distance distribution in the sample, the other one is the interaction of foreign entry and an indicator for those industries below or at that median. A discussion of these results is given in section 4.2 (IV.B) of the paper.

Bold numbers indicate coefficients. Standard errors in parentheses and italics are robust and allow for correlation between establishments within the same industry. Observations are weighted by employment and the inverse of their sampling probability.

Table A.8: Productivity growth – Alternative sets of instruments

	(1) IV	(2) IV	(3) IV	(4) IV	(5) IV	(6) IV	(7) IV	(8) IV	(9) IV	(10) IV
Dependent variable	Growth of labor productivity$_{ijt}$									
Foreign entry$_{jt-1}$ ×distance$_{jt-1}$(E^F×D)	**-0.062**	**-0.069**	**-0.073**	**-0.123**	**-0.061**	**-0.073**	**-0.073**	**-0.070**	**-0.254**	**-0.243**
	(0.026)	*(0.023)*	*(0.023)*	*(0.066)*	*(0.023)*	*(0.025)*	*(0.020)*	*(0.279)*	*(0.315)*	*(0.102)*
Foreign entry$_{jt-1}$(E^F)	**0.028**	**0.028**	**0.029**	**0.039**	**0.027**	**0.030**	**0.019**	**0.051**	**0.065**	**0.006**
	(0.003)	*(0.004)*	*(0.004)*	*(0.015)*	*(0.004)*	*(0.004)*	*(0.004)*	*(0.048)*	*(0.057)*	*(0.024)*
Distance to frontier$_{jt-1}$(D)	**0.089**	**0.091**	**0.092**	**0.098**	**0.089**	**0.087**	**0.085**	**0.084**	**0.137**	**0.155**
	(0.029)	*(0.030)*	*(0.030)*	*(0.026)*	*(0.029)*	*(0.029)*	*(0.027)*	*(0.073)*	*(0.091)*	*(0.044)*
Controls as in table 2 of the paper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test, entry terms E^F & E^F×D	40.69(2)	28.94(2)	30.45(2)	8.91(2)	30.01(2)	34.56(2)	12.83(2)	17.16(2)	18.99(2)	39.18(2)
χ^2-test of over-identifying restrictions	12.78(10)	10.79(10)	13.74(10)	13.14(10)	12.88(10)	13.03(10)	10.62(10)	0.59(2)	4.38(3)	just identified
Dependent variable	Growth of total factor productivity$_{ijt}$									
Foreign entry$_{jt-1}$ ×distance$_{jt-1}$(E^F×D)	**-0.133**	**-0.130**	**-0.131**	**-0.138**	**-0.128**	**-0.131**	**-0.137**	**-0.452**	**-0.139**	**-0.107**
	(0.027)	*(0.026)*	*(0.025)*	*(0.058)*	*(0.031)*	*(0.024)*	*(0.022)*	*(0.195)*	*(0.173)*	*(0.094)*
Foreign entry$_{jt-1}$(E^F)	**0.042**	**0.041**	**0.041**	**0.044**	**0.041**	**0.041**	**0.045**	**0.110**	**0.042**	**0.078**
	(0.005)	*(0.005)*	*(0.005)*	*(0.012)*	*(0.006)*	*(0.004)*	*(0.005)*	*(0.032)*	*(0.031)*	*(0.020)*
Distance to frontier$_{jt-1}$(D)	**0.106**	**0.104**	**0.105**	**0.098**	**0.105**	**0.102**	**0.106**	**0.183**	**0.108**	**0.085**
	(0.021)	*(0.021)*	*(0.020)*	*(0.021)*	*(0.021)*	*(0.021)*	*(0.022)*	*(0.059)*	*(0.051)*	*(0.044)*
Controls as in table 2 of the paper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test, entry terms E^F & E^F×D	73.90(2)	83.06(2)	80.39(2)	45.01(2)	74.29(2)	96.08(2)	65.03(2)	9.94(2)	38.47(2)	176.07(2)
χ^2-test of over-identifying restrictions	6.22(10)	4.73(10)	5.38(10)	4.93(10)	5.90(10)	5.50(10)	5.44(10)	3.71(2)	3.34(3)	just identified
Instrumented terms	E^F, E^F×D	E^F, E^F×D	E^F, E^F×D	E^F, E^F×D	E^F, E^F×D	E^F, E^F×D	E^F, E^F×D	E^F, E^F×D	E^F, E^F×D	E^F, E^F×D
Type of instruments	SMP, MM, P	SMP, MM, P	SMP, MM, P	SMP, MM, P	SMP, MM, P	SMP, MM, P	SMP, MM, P	SMP, MM, P	MM	P
Eliminated industry	248	2565	3204	361	371	432/438	475	/	/	/
Number of observations	25,042	25,365	25,188	25,279	25,072	24,926	23,756	25,388	25,388	25,388

Notes: In this table we show robustness of our results to the following variations of our main IV model specifications in table 2 of the paper, col. 5 and 10:

a) Col. 1 to 7: Sample variation by excluding one by one those industries individually controlled for in the set of instruments that is explained in section 4.1 (IV.A) of the paper and used in table 2, col. 5 and 10.
b) Col. 8: Instrumentation of both entry terms using four instruments that aggregate industries affected by the EU Single Market Program, U.K. privatization cases, U.K. merger cases and U.K. monopoly cases, respectively.
c) Col. 9: Instrumentation of both entry terms using U.K. Competition Authority merger and monopoly instruments only.
d) Col. 10: Instrumentation of both entry terms using U.K. privatization instruments only.

SMP indicates policy instruments capturing the EU Single Market Program, MM indicates policy instruments based on U.K. Competition Authority merger and monopoly cases, and P indicates U.K. privatization instruments. Bold numbers indicate coefficients. Standard errors in parentheses and italics are robust and allow for correlation between establishments within the same industry. Observations are weighted by employment and the inverse of their sampling probability. In rows with χ2- or F-test results degrees of freedom parameters are in parentheses (numerator degrees of freedom in case of F-tests). The results in this table are discussed in section 4.2 (IV.B) of the paper.

Table A.9: Robustness results – Specifications as in table 2 using unweighted data and as in table 4 with TFP growth as dependent variable

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) IV	(6) IV	(7) IV	(8) IV
Dependent variable	Growth of labor productivity$_{ijt}$		Growth of total factor productivity$_{ijt}$					
Foreign entry$_{jt-1}$×distance$_{jt-1}$(E^F×D)		**-0.031**		**-0.048**	**-0.133**	**-0.138**	**-0.130**	**-0.137**
		(0.010)		*(0.010)*	*(0.023)*	*(0.028)*	*(0.025)*	*(0.015)*
Foreign entry$_{jt-1}$(E^F)	**0.006**	**0.013**	**0.008**	**0.020**	**0.042**	**0.044**	**0.042**	**0.042**
	(0.003)	*(0.004)*	*(0.003)*	*(0.003)*	*(0.004)*	*(0.005)*	*(0.006)*	*(0.003)*
Domestic entry$_{jt-1}$×distance$_{jt-1}$					**0.003**			
					(0.003)			
Domestic entry$_{jt-1}$					**-0.001**			
					(0.002)			
Distance to frontier$_{jt-1}$(D)	**0.060**	**0.066**	**0.061**	**0.069**	**0.102**	**0.080**	**0.095**	**0.106**
	(0.015)	*(0.015)*	*(0.017)*	*(0.017)*	*(0.021)*	*(0.034)*	*(0.054)*	*(0.019)*
Import$_{jt-1}$×distance$_{jt-1}$						**0.027**		
						(0.023)		
Import penetration$_{jt-1}$(I)	**0.034**	**0.035**	**0.039**	**0.040**	**0.099**	**0.100**	**0.101**	**0.120**
	(0.020)	*(0.020)*	*(0.021)*	*(0.021)*	*(0.040)*	*(0.039)*	*(0.042)*	*(0.073)*
Competition$_{jt-1}$(C)	**0.100**	**0.097**	**0.169**	**0.164**	**0.137**	**0.138**	**0.145**	**0.142**
	(0.046)	*(0.045)*	*(0.048)*	*(0.047)*	*(0.040)*	*(0.040)*	*(0.046)*	*(0.040)*
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Establishment effects					Yes	Yes	Yes	Yes
four-digit industry effects	Yes	Yes	Yes	Yes				
Instrumented terms/Control function					E^F, E^F×D	E^F, E^F×D	E^F, E^F×D, **D**	E^F, E^F×D, **I**
Type of instruments					SMP, MM, P	SMP, MM, P	SMP, MM, P, U.S. Input	SMP, MM, P, U.S. Import
χ^2-test of over-identifying restrictions					5.71(10)	6.30(10)	7.21 (11)	5.96 (10)
Number of observations	25,388	25,388	25,388	25,388	25,388	25,388	25,388	25,388

Notes: The table displays OLS and IV estimates of productivity growth models. In columns 1 to 4 we use non-weighted observations, include four-digit industry effects and standard errors in parentheses and italics are robust and allow for correlation between establishments within the same industry-year. In columns 5 to 8 we weight observations by employment and the inverse of their sampling probability, include establishment effects and standard errors are robust and allow for correlation between establishments within the same industry. Bold numbers indicate coefficients. In the row with χ^2-test results degrees of freedom parameters are in parentheses. We use the following abbreviations for policy instruments: SMP: EU-Single Market Program; MM: U.K. Competition Authority merger and monopoly cases; P: U.K. privatization instruments; U.S. Input: industry-level U.S. capital-labor ratio and ratio of skilled over all workers; U.S. Import: industry-level U.S. import penetration. The results in this table are discussed in sections 4.2, 4.4.1 and 4.4.2 (IV.B and IV.D) of the paper.

Table A.10: Robustness results – Specifications including distance-competition interactions or allowing for endogeneity of covariates

	(1) IV	(2) IV	(3) IV	(4) IV	(5) ZIP-CF	(6) ZIP-CF	(7) ZIP-CF	(8) ZIP-CF
Dependent variable	Growth of labor productivity$_{ijt}$		Growth of total factor productivity$_{ijt}$		Number of patents$_{ijt}$			
Foreign entry$_{jt-1}$×distance$_{jt-1}$(E^F×D)	**-0.067**	**-0.077**	**-0.131**	**-0.138**	**-1.703**	**-1.620**	**-1.501**	**-1.569**
	(0.024)	*(0.019)*	*(0.029)*	*(0.020)*	*(0.595)*	*(0.647)*	*(0.622)*	*(0.613)*
Foreign entry$_{jt-1}$(E^F)	**0.027**	**0.030**	**0.045**	**0.056**	**0.513**	**0.487**	**0.454**	**0.472**
	(0.004)	*(0.006)*	*(0.007)*	*(0.006)*	*(0.174)*	*(0.187)*	*(0.184)*	*(0.180)*
Distance to frontier$_{jt-1}$(D)	**0.098**	**0.092**	**-0.033**	**0.077**	**-0.355**	**0.676**	**0.756**	**0.756**
	(0.180)	*(0.036)*	*(0.145)*	*(0.028)*	*(2.530)*	*(0.315)*	*(0.268)*	*(0.314)*
Import penetration$_{jt-1}$(I)	**0.084**	**0.086**	**0.100**	**0.122**	**1.830**	**3.525**	**1.596**	**1.623**
	(0.034)	*(0.040)*	*(0.039)*	*(0.045)*	*(0.774)*	*(1.908)*	*(0.770)*	*(0.789)*
Import$_{jt-1}$ squared(I^2)					**-0.601**	**-1.124**	**-0.604**	**-0.636**
					(0.293)	*(0.559)*	*(0.284)*	*(0.287)*
Competition$_{jt-1}$×distance$_{jt-1}$	**-0.008**		**0.159**		**1.359**			
	(0.182)		*(0.160)*		*(2.741)*			
Competition$_{jt-1}$(C)	**0.077**	**0.119**	**0.106**	**0.789**	**33.717**	**32.531**	**49.963**	**39.538**
	(0.044)	*(0.320)*	*(0.041)*	*(0.300)*	*(17.131)*	*(17.250)*	*(18.366)*	*(22.981)*
Competition$_{jt-1}$ squared(C^2)					**-18.937**	**-18.018**	**-24.807**	**-19.311**
					(9.721)	*(9.692)*	*(10.057)*	*(13.178)*
Controls as in table 2 in the paper	Yes	Yes	Yes	Yes				
Controls & inflation model as in table 3					Yes	Yes	Yes	Yes
Instrumented terms/Control function	E^F, E^F×D	E^F, E^F×D, **C**	E^F, E^F×D	E^F, E^F×D, **C**	E^F, E^F×D	E^F, E^F×D, **I, I^2**	E^F, E^F×D, **C**	E^F, E^F×D, **C, C^2**
Type of instruments	SMP, MM, P	SMP, MM, P, U.S. C	SMP, MM, P	SMP, MM, P, U.S. C	SMP, MM, P	SMP, MM, P, U.S. I & U.S. I^2	SMP, MM, P, U.S. C	SMP, MM, P, U.S. C & U.S. C^2
χ^2-test of over-identifying restrictions	13.71(10)	12.77(10)	6.41(10)	13.37(10)				
Number of observations	25,388	25,388	25,388	25,388	1,073	1,073	1,073	1,073

Notes: The table displays IV estimates of productivity growth models in col. 1 to 4, where observations are weighted by employment and the inverse of their sampling probability and standard errors in parentheses and italics are robust and allow for correlation between establishments within the same industry. Zero-inflated poisson estimates with control function are shown in col. 5 to 8. The inflation model is specified as in table 3 and standard errors in these columns are robust and allow for correlation between firms within the same industry-year. Bold numbers indicate coefficients. In the row with χ^2-test results degrees of freedom parameters are in parentheses. We use the following abbreviations for policy instruments: SMP: EU Single Market Program; MM: U.K. Competition Authority merger and monopoly cases; P: U.K. privatization instruments; U.S. I: industry-level U.S. import penetration; U.S. I^2: U.S. import penetration squared; U.S. C: industry-level U.S. index of profitability; U.S. C^2: U.S. profitability index squared. In col. 6 we use as control function terms the residuals from a first stage entry, entry-distance, import and import squared equation. In col. 8 we proceed analogously for competition. The results in this table are discussed in sections 4.4.1 and 4.4.2 (IV.D) of the paper.

Table A.11: Robustness results – Expanded sets of covariates

	(1) OLS	(2) OLS	(3) IV	(4) OLS	(5) OLS	(6) IV	(7) OLS	(8) OLS	(9) IV
Dependent variable					Growth of labor productivity$_{ijt}$				
Foreign entry$_{jt-1}$ ×distance$_{jt-1}$(E^F×D)		**-0.040**	**-0.093**		**-0.043**	**-0.077**		**-0.046**	**-0.092**
		(0.016)	*(0.023)*		*(0.014)*	*(0.023)*		*(0.014)*	*(0.018)*
Foreign entry$_{jt-1}$(E^F)	**0.0005**	**0.013**	**0.040**	**0.006**	**0.016**	**0.028**	**0.011**	**0.022**	**0.037**
	(0.006)	*(0.007)*	*(0.012)*	*(0.004)*	*(0.003)*	*(0.004)*	*(0.003)*	*(0.003)*	*(0.003)*
Distance to frontier$_{jt-1}$(D)		**0.087**	**0.098**		**0.087**	**0.094**		**0.088**	**0.098**
		(0.029)	*(0.027)*		*(0.028)*	*(0.030)*		*(0.028)*	*(0.030)*
Establishment size$_{jt-1}$×foreign entry$_{jt-1}$	**0.015**	**0.007**	**-0.016**						
	(0.009)	*(0.009)*	*(0.015)*						
Establishment size$_{jt-1}$	**-0.009**	**0.003**	**0.009**						
	(0.012)	*(0.015)*	*(0.014)*						
Working owner share$_{jt-1}$×foreign entry$_{jt-1}$				**0.324**	**0.308**	**0.196**			
				(0.148)	*(0.120)*	*(0.173)*			
Working owner share$_{jt-1}$				**-0.101**	**-0.113**	**-0.100**			
				(0.094)	*(0.090)*	*(0.087)*			
Capital-labor-ratio$_{jt-1}$×foreign entry$_{jt-1}$							**-0.152**	**-0.233**	**-0.377**
							(0.104)	*(0.080)*	*(0.123)*
Capital-labor-ratio$_{jt-1}$							**0.771**	**0.868**	**0.920**
							(0.232)	*(0.196)*	*(0.171)*
Controls as in table 2 of the paper		Yes	Yes		Yes	Yes		Yes	Yes
Year and establishment effects	Yes			Yes			Yes		
Instrumented terms			E^F, E^F×D			E^F, E^F×D			E^F, E^F×D
Type of instruments			SMP, MM, P			SMP, MM, P			SMP, MM, P
χ^2-test of over-identifying restrictions			13.20(10)			13.46(10)			10.38(10)
Number of observations	25,388	25,388	25,388	25,388	25,388	25,388	25,388	25,388	25,388

Notes: This table displays OLS and IV labor productivity regressions where we introduce additional industry-level variables and their interactions with foreign entry. These results are discussed in section 4.4.3 (IV.D) of the paper. Bold numbers indicate coefficients. Standard errors in parentheses and italics are robust and allow for correlation between establishments within the same industry. Observations are weighted by employment and the inverse of their sampling probability. In the row with χ^2-test results degrees of freedom parameters are in parentheses. SMP indicates policy instruments capturing the EU Single Market Program, MM indicates policy instruments based on U.K. Competition Authority merger and monopoly cases, and P indicates U.K. privatization instruments.

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