The Effects of Entry on Incumbent Innovation and Productivity

THE EFFECTS OF ENTRY ON INCUMBENT INNOVATION AND PRODUCTIVITY

Philippe Aghion, Richard Blundell, Rachel Griffith, Peter Howitt, and Susanne Prantl*

Abstract—How does firm entry affect innovation incentives in incumbent firms? Microdata suggest that there is heterogeneity across industries. Specifically, incumbent productivity growth and patenting is positively correlated with lagged greenfield foreign firm entry in technologically advanced industries, but not in laggard industries. In this paper we provide evidence that these correlations arise from a causal effect predicted by Schumpeterian growth theory—the threat of technologically advanced entry spurs innovation incentives in sectors close to the technology frontier, where successful innovation allows incumbents to survive the threat, but discourages innovation in laggard sectors, where the threat reduces incumbents' expected rents from innovating. We find that the empirical patterns hold using rich micro panel data for the United Kingdom. We control for the endogeneity of entry by exploiting major European and U.K. policy reforms, and allow for endogeneity of additional factors. We complement the analysis for foreign entry with evidence for domestic entry and entry through imports.

I. Introduction

THERE is a long-standing interest in the effects of entry, which are widely recognized as major drivers of economic growth. Entry can induce reallocation of inputs and outputs, trigger knowledge spillovers, and affect innovation incentives in incumbent firms. The desire to induce entry by foreign firms has spurred widespread policy reforms, particularly in countries or industries behind the technology frontier. However, empirical studies of the effects of market liberalizations and inward direct investment from foreign firms provide mixed results on incumbent reactions.[1] In this paper we explore systematic variation in the response of incumbent firms to entry.

We are motivated by the following empirical regularity—we see substantial heterogeneity in the correlation between greenfield foreign firm entry and incumbent productivity growth when we look across industries in the United Kingdom. In industries close to the technology frontier there is a strong and positive correlation, while a weak or even negative one is found in industries that lag behind. This is illustrated in figure 1, where we plot the annual rate of greenfield foreign firm entry in each industry-year against the respective average of subsequent total factor productivity growth in incumbent establishments. The sample is split at the median distance to the technology frontier, as measured by a labor productivity index that relates incumbents in U.K. industries to their U.S. industry equivalent.

Our explanation for this variation follows from Schumpeterian growth theory—threat from frontier entrants induces incumbents in sectors that are initially close to the technology frontier to innovate more, and this triggers productivity growth, but entry threat reduces the expected rents from doing R&D for incumbents in sectors further from the frontier. In the former case, incumbent firms close to the frontier know that they can escape and survive entry by innovating successfully, and so they react with more intensive innovation activities aimed at escaping the threat. In the latter case, incumbents further behind the frontier have no hope to win against an entrant. The escape-entry effect in advanced industries is similar to the escape-competition effect developed in Aghion et al. (2001). The discouragement effect in lagging industries is similar to the Schumpeterian appropriability effect of product market competition. Systematic variation of innovation activity with distance to the technology frontier was introduced into Schumpeterian theory by Howitt and Mayer-Foulkes (2005) and, more closely related to this paper, by Acemoglu, Aghion, and Zilibotti (2006).

Building on this theoretical background, we provide an empirical analysis of the variation of incumbent reaction to entry with distance to the technology frontier. We investigate how incumbent (labor and total factor) productivity growth and patenting reacts to entry and find results that mirror the theoretical predictions. The main identification problem that we address arises because entry threat is not observable and it is endogenous to incumbent performance. We use actual foreign firm entry as a proxy for the unobservable entry threat, which, if anything, exacerbates the endogeneity problem (see discussion in section IIB). To tackle this we exploit variation in U.K. entry conditions that arises from a major policy reform in the European Union, the Single Market Program, and from a series of U.K. product market reforms in combination with rich micro panel data. We provide two interesting insights. First, we find a consistent pattern of variation in incumbents' reactions to foreign firm entry using either U.K. policy reforms or EU-wide policy reforms—a finding that may reduce political-economy concerns about using country-specific policy instruments in our context. Second, while our main

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[1] See, inter alia, Aitken and Harrison (1999), Pavcnik (2002), and Javorcik (2004).

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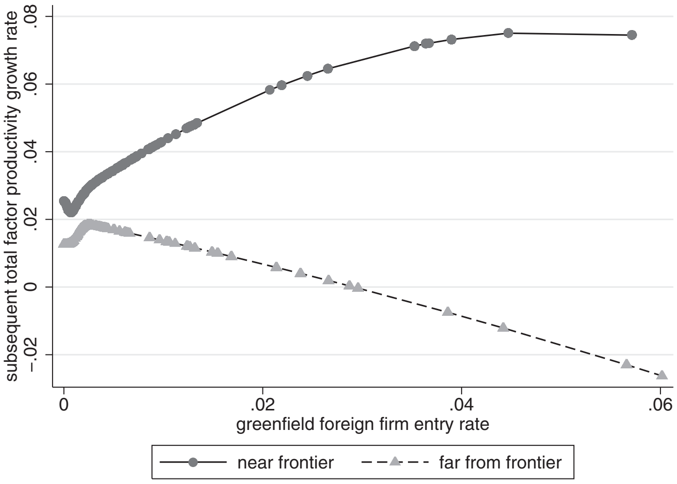
FIGURE 1.—REACTIONS TO ENTRY IN INCUMBENTS NEAR AND FAR FROM THE TECHNOLOGY FRONTIER



Notes: The figure plots spline estimates of the relation between the greenfield foreign firm entry rate and subsequent total factor productivity growth of domestic incumbent establishments in U.K. four-digit industries, 1987 to 1993. Each dot represents the productivity growth estimate for establishments in one industry-year cell. The spline regression includes time and industry fixed effects. Three spline points are chosen such that all establishment observations in industry-year cells with nonzero entry are grouped into four equally sized classes. The distance to the technology frontier is a labor productivity index relating incumbents in four-digit U.K. industries to their U.S. industry equivalent. The top curve (with dots) is for establishments in industry-year cells near the technology frontier (less or equally distant to the frontier as the year-specific median of the distance distribution in the sample). The bottom curve (with triangles) is for establishments further behind the technology frontier (more distant to the frontier than the sample median).

model specifications include distance to frontier and control variables such as import penetration and profitability that are assumed exogenous, we find similar effects of entry when we allow for endogeneity of these variables. These findings relate our work to the literature on competition and trade. We complement our main analysis by considering whether different forms of entry have different impacts, specifically entry by domestic firms or entry through import, and we explore why the two most likely alternative interpretations—based on knowledge spillovers—are not consistent with the full pattern of our empirical results.

Our analysis relates to several different strands of empirical work. First, there is the empirical literature on the effects of trade liberalization and inward direct investment from foreign firms. Studies including Aitken and Harrison (1999), Pavcnik (2002), and Javorcik (2004) are, as ours, based on plant or firm panel data and exploit variation of trade or foreign firm activity across industries and time.[2] Aghion et al. (2004), Griffith, Redding, and Simpson (2002), and Haskel, Pereira, and Slaughter (2007) show for U.K. industries positive correlations of (increases in) the employment share in foreign firms and average growth of total factor productivity in domestic producers. In contrast to this, we use direct entry measures and focus on investigating systematic variation in incumbent innovation and productivity reactions to entry with distance to the technology frontier. Aghion et al. (2005b, 2006) use state-industry panel data instead of plant or firm panel data to investigate how the effectiveness of the Indian liberalization reform depends on the technological and institutional state-industry environment, in particular labor market regulation. Second, there is the empirical industrial organization literature following the work of Bresnahan and Reiss (1990, 1991) and Berry (1992). Berry and Reiss (2006) survey structural econometric models with entry in well-defined, mostly oligopolistic markets and endogenous market structure and discuss the insights gained into the determinants of firms' entry decisions, the importance of firm heterogeneity, and the nature of competition. Olley and Pakes (1996) investigate the effects of deregulation on aggregate productivity growth and the underlying reallocation mechanism in one particular industry. Our emphasis is instead on within-firm changes in innovation incentives and in variation of entry effects on incumbent performance across markets. Another related strand is the literature on product market competition, firm performance, and innovation, in particular Nickell (1996), Blundell, Griffith, and Van Reenen (1999), and Aghion et al. (2005a). Aghion et al. present evidence on an inverted-U relationship between product market competition and innovative activity and find this to be steeper in neck-and-neck industries. Aghion and Griffith (2005) survey recent theoretical and empirical literature on competition, entry and growth, and the relevance of distance to frontier. Aghion and Howitt (2006) focus on policy implications.

The paper is organized as follows. In section II we discuss the theoretical background and empirical modeling. In section III we describe our data. Empirical results are presented in section IV and section V concludes.

II. Variation of Entry Effects with Distance to Frontier

A. *Theoretical Background*

Variation of entry effects on incumbent performance, depending on distance to the technology frontier, follows from Schumpeterian growth models with escape-entry and discouragement effects:

- Increasing the threat of frontier entry induces incumbents in sectors that are close to the technology frontier to innovate more in order to escape entry. It reduces incumbents' incentives to innovate in sectors that are further behind the frontier, where there is little hope of surviving entry.
- Increasing frontier entry threat has a more positive effect on incumbent productivity growth in sectors that are closer to the frontier than in sectors further behind the frontier.

The idea of the escape-entry effect is similar to the idea of the escape-competition effect as developed in Aghion et al. (2001). In that model each industry is assumed to be a

[2] See also, for example, Amiti and Konings (2005), Bertschek (1995), and Keller and Yeaple (2007).

duopoly, with two permanent rivals, and the degree of competition is measured by the elasticity of demand between the rivals' products. Here we consider a model in which the rivals are constantly threatened with extinction by frontier innovators and there is an infinite cross-elasticity of demand. This leads to the escape-entry effect. Both of these models assume step-by-step innovation instead of the leapfrogging assumed in earlier Schumpeterian models. To derive the escape-entry effect what is needed is that the probability that a frontier incumbent survives frontier entry is higher than the probability that a lagging incumbent survives.[3] The discouragement effect in lagging industries is similar to the Schumpeterian appropriability effect of product market competition. Systematic variation of innovation activity with distance to the technology frontier was introduced into Schumpeterian theory by Howitt and Mayer-Foulkes (2005) and Acemoglu, Aghion, and Zilibotti (2006).

Related theory papers are, in particular, Gilbert and Newbery (1982) on preemption and Laffont and Tirole (1993) on the welfare effects of entry regulation in a model of product differentiation. Laffont and Tirole concentrate on how regulation affects the size of innovations, or the extent of differentiation, by entrants and do not allow for incumbent innovation. Fudenberg and Tirole (1984) and Tirole (1988) analyze strategic interaction between entrants and incumbents. Barro and Sala-i-Martin (2004) and Aghion et al. (2005a) focus on competition among incumbent firms and its effects on growth, but do not consider entry. Reallocative effects of globalization and trade liberalization are analyzed in Melitz (2003) and Bernard et al. (2003). We focus instead on entry effecting growth through within-firm innovation effects in incumbents.

B. *Empirical Modeling*

The descriptive evidence in figure 1 is clearly not sufficient to establish a causal relationship from entry to innovation and productivity growth or that it depends on distance to the technology frontier. The central empirical relationship we are interested in is of the following form:

$$Y = f(P, D, X), \tag{1}$$

where Y is a measure of incumbent performance, P is entry threat, D is the distance to frontier, and X is a vector of further covariates.

We address a number of issues that arise when exploring this relationship empirically. First, entry threat P is unobservable and potentially endogenous in incumbent performance equations. We use lagged actual entry to proxy the unobservable entry threat and, in doing so, we face the same endogeneity problem as with entry threat, if anything in aggravated form.[4] We discuss the endogeneity of entry below and outline our identification strategy. Second, we focus on how the effects of frontier entry vary with distance to the frontier. We measure technologically advanced entry by considering foreign firm entry, and to measure distance to the frontier we use a labor productivity index that relates incumbents in U.K. industries to their U.S. industry equivalent. In our preferred specification the two continuous measures enter linearly and with an interaction. We also consider endogeneity of the distance to the frontier, check whether the distance measure may capture other industry-specific influences, and provide results for other forms of entry. Third, there are important covariates that may determine the performance of incumbents in addition to entry—most important, we think of effects triggered by trade relations and other factors that affect competition, market structure, and the rents earned by incumbents. We control for these using observable and unobservable characteristics in our main empirical specifications, and in extended specifications we allow for endogeneity of our main control variables. Fourth, to measure incumbent performance we use two measures of productivity growth, as well as a count of patents.

To start with we measure incumbent performance as growth of labor productivity at the establishment level (ΔLP_{ijt}) and specify the following relation:

$$\begin{aligned} \Delta LP_{ijt} = \alpha + \beta_1 E_{jt-1} + \beta_2 D_{jt-1} + \beta_3 E_{jt-1} D_{jt-1} \\ + X'_{ijt-1}\gamma + \tau_t + \eta_i + u_{ijt}, \end{aligned} \tag{2}$$

where i indexes incumbent establishments, j indexes industries, t indexes years, and E is actual greenfield foreign firm entry. To control for different permanent levels of productivity growth across establishments we include individual fixed effects η_i. Common macro shocks are captured by time dummies τ_t. We also use growth of total factor productivity, which may account for systematic variation in factor inputs not captured in labor productivity growth.

Both measures of productivity growth could, however, also reflect advances due to imitation of entrants with superior technologies rather than innovative activity. Thus, we also use a count of patents as a measure of incumbent performance to check more directly whether our results are picking up changes in firms' innovative activity. There are a large number of firm-year observations with zero patents in our data, so we estimate a zero-inflated Poisson model

[3] In section 1 of the Web appendix, we derive the escape-entry effect from the extreme assumption that a frontier incumbent survives frontier entry with probability 1, while a lagging incumbent survives with probability 0. A simplified version of this model with a fixed entry probability is sketched in Aghion et al. (2004), Aghion and Griffith (2005), and Aghion and Howitt (2006). Aghion et al. (2005b) present a closely related model.

[4] In our theoretical context actual entry and entry threat are identical in industries far behind the frontier, where entrants can never lose against incumbents. In industries closer to the frontier actual entry and entry threat differ in situations where entrants may lose, but they will be positively correlated as long as incumbent innovation aimed at escaping entry is not too successful in the sense of entry prevention (Web appendix, sections 1.2 and 1.6).

(Greene, 1994; Lambert, 1992). This also relaxes the restrictive feature of the Poisson distribution that imposes equality of the variance and the mean. We model the probability of being granted at least one patent as a function of a firm's presample stock of patents. Conditional on having at least one patent, we specify the innovation rate as

$$n_{ijt} = \exp(\alpha + \beta_1 E_{jt-1} + \beta_2 D_{jt-1} + \beta_3 E_{jt-1} D_{jt-1} + X'_{ijt-1}\gamma + \tau_t + \eta_j), \tag{3}$$

where i indexes incumbent firms, j indexes industries, t indexes years, and η_j indicates industry fixed effects. All other variables and parameters are defined as above. To take unobservable firm-specific, time-invariant heterogeneity in patent behavior into account we follow Blundell et al. (1999) and use presample information on firms' patent stocks.

C. *Identification and Instruments*

The key identification issue that we tackle in this paper is the fact that entry can be endogenous to innovation and productivity growth. When considering entry into a new market potential entrants are likely to take into account the productivity and innovative activity of local incumbents. We expect a negative covariance between actual entry and the error term in incumbent performance equations when industries are close to the frontier, but not necessarily in industries far from the frontier.[5]

We use two broad sets of policy reforms for instrumenting entry—reforms at the European level and reforms at the U.K. level that changed entry costs and effected entry differentially across industries and time.[6] In our main model specifications we endogenize the linear entry term as well as its interaction with the distance to frontier. We show results using different sets of policy instruments: instruments that capture the EU Single Market Program only, U.K. policy instruments only, and these instruments pooled.[7] The European policy instruments indicate industries in which reforms undertaken as part of the SMP were ex ante expected to reduce medium or high entry barriers. The U.K. reforms include privatization cases—the Thatcher government embarked on a large-scale privatization program before similar programs were implemented in other countries. A substantial portion of government-owned assets were sold and, in most cases, the privatization decisions resulted in opening up markets to firm entry. We use instruments that reflect the respective stock market sales in directly affected industries. The U.K. reforms also include merger and monopoly cases where investigations of the U.K. Competition Authority culminated in policy interventions. For each affected industry we construct a variable that indicates the dates on which undertakings of inquiries were first publicly announced.[8]

In extended model specifications we allow for endogeneity of the distance to the technology frontier. This is to address the concern that imposing exogeneity of that variable may affect findings on the variation of entry effects with distance to frontier. We augment the set of instruments with U.S. variables on production inputs that correlate with the distance to frontier, but should not depend directly on anticipated developments in U.K. incumbent performance.

The policy interventions that we use for instrumenting entry may also affect innovation incentives and productivity growth through other channels, especially through changing trade relations or the competitive environment. Thus, we pay attention in our main specifications to controlling for trade and competition, and assume that the instruments have no additional impact on incumbent performance, after conditioning on these covariates. We test the overidentifying restrictions in these specifications and experiment with using subsets of our policy instruments. In addition, we allow for endogeneity of the trade and competition covariate by adding U.S. trade and competition variables as instruments, and relying on the additional assumption that the full set of instruments affects entry, its interaction with the distance to frontier, and the instrumented covariate differentially.

III. Data and Descriptive Statistics

A. *Data*

We combine microdata from several sources. Most important, we use comprehensive establishment-level panel data for Great Britain from the U.K. Office for National Statistics (ONS) Annual Respondents Database (ARD) for estimating productivity growth models. It is a legal obligation for firms to report these data. Innovation models are estimated using firm-level accounting data from Data Stream that are matched to patent data from the NBER/Case Western Patent Database for a panel of firms listed on the London Stock Exchange (LSE). These firms account for a large proportion of U.K. R&D activity.[9]

Productivity growth: Our key performance indicator is productivity growth, which we measure using the disaggregated ARD panel data on establishment inputs and outputs.

[5] In line with our theory framework foreign firms are more likely to enter industries that are close to frontier if their relative advantages are high and they anticipate this correctly.

[6] Controlling for unobservable individual, time-invariant heterogeneity and for time effects, as we also do, is unlikely to be sufficient to address entry endogeneity, since industry-specific, time-varying changes of incumbent performance should affect entry. Even lagging entry measures will not fully solve the problem if entrants anticipate changes to the distribution of U.K. incumbent performance and this leads to relative changes in entry across industries.

[7] We apply IV estimation techniques in linear models, and a control function approach in nonlinear patent count models. In linear models, control function and IV coefficient estimates coincide. See Wooldridge (2002) or Blundell and Powell (2003).

[8] See section 2.2 and table A.4, both in the Web appendix, for further details.

[9] Section 2 in the Web appendix provides further details on the data and the construction of variables.

We calculate growth of labor productivity (LP) as growth in real output per employee. To determine growth in total factor productivity (TFP) we implement a superlative index number approach, smoothing observed factor shares in order to mitigate potential consequences of measurement error. We check that our empirical results are robust to not smoothing factor shares and to not imposing perfect competition.[10]

Innovation: We measure innovation using the count of patents firms take out in the U.S. Patent Office. Focusing on U.S. patents of U.K. firms to measure innovation is advantageous in our context, since U.K. firms are unlikely to patent low-value inventions in the United States.

Entry: Our focus in this paper is on technologically advanced entry, which we measure by greenfield entry of foreign firms. This captures entry from firms that set up new production facilities in Great Britain, and which operate internationally and are thus most likely to produce at the technological frontier.[11] Using panel data at the plant level from the ARD we calculate the annual greenfield foreign firm entry rate as the share of industry employment in entrants that meet the following conditions: the entering firm (i) starts producing in one or more *new* British production sites in the year considered, (ii) is foreign owned, and (iii) did *not* already operate beforehand in the respective industry in Great Britain.

Our measure has several advantages over other foreign entry measures that are commonly used. In contrast to counting the number of foreign entrants, it takes the size of entrants into account. Compared with financial flows of inward direct investment the pattern of new real production activity in foreign firms is directly reflected. In contrast to our earlier work (Aghion et al., 2004) and related literature, which use industry-level measures of employment in foreign firms or equity owned by foreign investors,[12] we focus on greenfield entry. This has the advantage of reflecting the scale of entry, but not reallocation between domestic and foreign owners via acquisition, takeover, or merger activities.

Greenfield entry of domestic firms is calculated in a similar way and used below to proxy entry further behind the frontier. The value range for our entry measures is 0 to 100.

Distance to the technology frontier: We capture the distance of incumbents in each U.K. industry to its U.S. industry equivalent using a three-year moving average of U.S. industry labor productivity relative to labor productivity in the respective incumbent U.K. industry. We average over the current and the two preceding years. We use U.S. industries because they most often represent the world technological frontier, or are at least ahead of the United Kingdom.[13] Thus, U.S. industries can trigger technologically advanced entry into the United Kingdom, and a large share of foreign entrants in Britain are indeed U.S.-owned.[14] The distance calculation uses U.S. industry panel data from the NBER manufacturing productivity database and U.K. data from the ARD. In addition to using a moving average, we also try alternative measures with other technology metrics and we use discrete versions of the variables to address concerns about measurement error.

Other variables: To measure trade activity we use the ratio of industry import over output from OECD STAN panel data. To capture the variation of competitive conditions across industries and time we calculate an index of average profitability in incumbent establishments based on ARD panel data. The index varies between 0 and 1 and takes the value of 1 in case of perfect competition. Presample information on patenting activity is summarized using a continuous patent stock variable based on patents dating back to 1968 along with a simple indicator of presample patent activity for firms in the panel of LSE-listed firms.

B. *Descriptive Statistics*

To estimate productivity growth models we use an unbalanced panel of 25,388 observations on 5,161 domestic incumbent *establishments* in 180 four-digit industries (based on U.K. SIC 80) over the period 1987 to 1993.[15] Of these, 81% are older than ten years when entering the sample. They have on average 263 employees between 1987 and 1993 and real output of £9m in 1980 pounds. Growth of LP is on average 0.9% and TFP growth is −1.1%. This reflects the recession in the early 1990s; the corresponding figures for the years 1987 and 1990 are 2.3% and 1.0%, respectively.

Innovation models are estimated using an unbalanced panel of 1,073 observations on 174 incumbent *firms* in 60 three-digit industries between 1987 and 1993. Seventy-four percent of these firms were listed on the LSE for more than a decade at sample entry. On average, they employ 8,286 people during the period 1987 to 1993 and have real sales of £433m in 1980 pounds. About 60% take out at least one patent at the U.S. Patent Office. As typically found, the sample distribution of patent counts is highly skewed—many firms do not patent, some patent a little, and a small number of firms are granted many patents per year.

[10] See table A.7 in the Web appendix.

[11] Multinational firms have been shown to be more productive on average than firms that operate only nationally. For the United Kingdom see Bloom, Sadun, and Van Reenen (2007), Criscuolo and Martin (2005), and Griffith and Simpson (2004), among others.

[12] See, among others, Aitken and Harrison (1999), Griffith et al. (2002), Haskel et al. (2007), and Javorcik (2004).

[13] See, inter alia, Griffith, Redding, and Van Reenen (2004).

[14] For the time period 1986 to 1992 the ARD data show that, on average, 36% of all greenfield foreign entrants in British manufacturing industries are under U.S. ownership.

[15] As we would expect in line with the theory framework we find that our main results are stronger when we restrict the sample to incumbents that are more likely to be industry leaders than they are in the complementing subsamples (Web appendix, table A.7).

Given our interest in studying how entry effects vary with distance to the industry-specific technology frontier, an important prerequisite for our empirical analysis is substantial variation in the sample distance distribution. Thus, note that about 20% of all four-digit industry-years in our data are at or close to the frontier (less than 3.5% behind their U.S. industry equivalent), while another 20% are at least 50% behind. It is also crucial that we have variation in entry rates at different distances to the frontier: there are four-digit industry-years with no, some, or substantial greenfield foreign firm entry in each quartile of the distance distribution. In addition, comparing quartile-specific distributions we see considerable overlap of these for the entry rate, the number of employees in entering firms, and entrants' size.[16]

IV. Empirical Results

To investigate the economic mechanism behind the descriptive evidence in figure 1 we analyze how the effects of frontier entry on incumbent innovation and productivity vary with the distance to the technology frontier, allowing for endogeneity of entry and controlling for possible confounding factors. We address a number of potential robustness concerns, take other forms of entry into account, and conclude by explaining why the most likely alternative interpretations do not fully explain our empirical findings.

A. *Entry*

The key identification issue that we address in our empirical analysis is the potential endogeneity of entry to productivity growth and patenting. We instrument greenfield foreign firm entry using major EU and U.K. policy reforms that aimed at changing entry costs during the 1980s and early 1990s. In table 1 we first show how the separate types of policy reforms relate to entry (columns 1–4), then we present our main first-stage regressions for entry and the interaction of entry and distance to the technology frontier (columns 5–10). These are used in the second-stage estimations in table 2 and include all exogenous variables from the second-stage equations.

In column 1 of table 1 we relate the EU-wide Single Market Program (SMP) to greenfield foreign firm entry, and constrain the EU-SMP coefficient to be common across all affected industries. The positive and significant coefficient indicates that the EU-SMP led to increased entry—a result that is consistent with ex ante expectations. In column 2 we use information on industries that are directly affected by the U.K. privatization program, again constraining the coefficient to be the same across industries, and find a positive and significant coefficient, just as we do in column 3 considering all U.K. merger cases where investigations of the U.K. Competition Authority triggered subsequent policy interventions. In column 4 with U.K. monopoly cases that

[16] Tables A.2 and A.3 in the Web appendix provide more details on these issues; descriptive statistics on the estimation samples are in table A.1.

TABLE 1.—ENTRY: BASIC MODELS AND FIRST-STAGE EQUATIONS

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS	(9) OLS	(10) OLS
Dependent variable	Foreign entry$_{jt-1}$	Foreign entry$_{jt-1}$	Foreign entry$_{jt-1}$	Foreign entry$_{jt-1}$	Foreign entry$_{jt-1}$	Foreign entry$_{jt-1}$× Distance$_{jt-1}$	Foreign entry$_{jt-1}$	Foreign entry$_{jt-1}$× Distance$_{jt-1}$	Foreign entry$_{jt-1}$	Foreign entry$_{jt-1}$× Distance$_{jt-1}$
EU Single Market Program$_{jt-1}$ (SMP)	**0.156** *(0.029)*				**0.120** *(0.019)*	**0.031** *(0.007)*			**0.031** *(0.014)*	**0.019** *(0.006)*
U.K. privatization cases$_{jt-1}$ (P)		**0.305** *(0.102)*					**0.201** *(0.030)*	**0.064** *(0.013)*	**0.204** *(0.029)*	**0.070** *(0.013)*
U.K. merger cases$_{jt-1}$ (MM)			**0.078** *(0.030)*				**0.090** *(0.047)*	**−0.001** *(0.013)*	**0.127** *(0.049)*	**0.004** *(0.013)*
U.K. monopoly cases$_{jt-1}$ (MM)				**−0.651** *(0.074)*			**0.024** *(0.103)*	**−0.045** *(0.050)*	**0.032** *(0.102)*	**−0.044** *(0.049)*
Additional industry-specific reform controls					248, 361, 371, 432/438	248, 361, 371, 432/438	2565, 3204, 361, 475	2565, 3204, 361, 475	248, 2565, 3204, 361, 371, 432/438, 475	248, 2565, 3204, 361, 371, 432/438, 475
Distance to frontier, import, and competition effects					Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Establishment effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test, SMP variables	28.33(1)				26.81(5)	27.61(5)			19.99(5)	25.27(5)
F-test, P variables		8.98(1)					25.69(2)	13.66(2)	27.56(2)	15.09(2)
F-test, MM variables			6.74(1)	77.46(1)			94.16(5)	77.35(5)	92.60(5)	74.50(5)
F-test, all excl. instruments					26.81(5)	27.61(5)	77.24(7)	62.31(7)	53.03(12)	47.41(12)
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 shows OLS estimates of basic entry models and of first-stage equations for the sample of 25,388 observations on 5,161 domestic incumbent establishments between 1987 and 1993. 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 first-stage equations are EU-SMP instruments only in columns 5 and 6, U.K. policy instruments only in columns 7 and 8, and these instruments pooled in columns 9 and 10. 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 2.—Productivity Growth: OLS Estimates and Second-Stage Equations

	(1) OLS	(2) OLS	(3) IV	(4) IV	(5) IV	(6) OLS	(7) OLS	(8) IV	(9) IV	(10) IV
Dependent variable	Growth of labor productivity$_{ijt}$					Growth of total factor productivity$_{ijt}$				
Foreign entry$_{jt-1}$ × distance$_{jt-1}$($E^F \times D$)		**−0.043**	**−0.071**	**−0.055**	**−0.073**		**−0.054**	**−0.123**	**−0.130**	**−0.132**
		(0.013)	*(0.031)*	*(0.020)*	*(0.023)*		*(0.015)*	*(0.034)*	*(0.026)*	*(0.024)*
Foreign entry$_{jt-1}$(E^F)	**0.008**	**0.018**	**0.022**	**0.028**	**0.029**	**0.007**	**0.020**	**0.041**	**0.041**	**0.042**
	(0.004)	*(0.002)*	*(0.010)*	*(0.002)*	*(0.004)*	*(0.003)*	*(0.003)*	*(0.010)*	*(0.004)*	*(0.004)*
Distance to frontier$_{jt-1}$(D)	**0.077**	**0.087**	**0.095**	**0.088**	**0.093**	**0.077**	**0.089**	**0.103**	**0.106**	**0.106**
	(0.029)	*(0.028)*	*(0.029)*	*(0.030)*	*(0.030)*	*(0.019)*	*(0.019)*	*(0.021)*	*(0.022)*	*(0.020)*
Import penetration$_{jt-1}$	**0.084**	**0.084**	**0.085**	**0.084**	**0.084**	**0.099**	**0.100**	**0.100**	**0.100**	**0.100**
	(0.033)	*(0.033)*	*(0.033)*	*(0.034)*	*(0.034)*	*(0.036)*	*(0.037)*	*(0.036)*	*(0.040)*	*(0.039)*
Competition$_{jt-1}$	**0.084**	**0.076**	**0.067**	**0.081**	**0.074**	**0.162**	**0.151**	**0.143**	**0.140**	**0.140**
	(0.034)	*(0.030)*	*(0.033)*	*(0.034)*	*(0.033)*	*(0.050)*	*(0.044)*	*(0.046)*	*(0.041)*	*(0.040)*
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Establishment effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Instrumented terms			E^F, $E^F \times D$	E^F, $E^F \times D$	E^F, $E^F \times D$			E^F, $E^F \times D$	E^F, $E^F \times D$	E^F, $E^F \times D$
Type of instruments			SMP	MM, P	SMP, MM, P			SMP	MM, P	SMP, MM, P
χ^2 test of overidentifying restrictions			5.67(3)	7.96(5)	13.65(10)			1.23(3)	4.59(5)	6.06(10)
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 and IV estimates of productivity growth models for the sample of 25,388 observations on 5,161 domestic incumbent establishments between 1987 and 1993. In columns 3–5 and 8–10 we allow for entry endogeneity in the linear and interacted entry terms. 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.

triggered policy interventions the coefficient is negative and significant. However, if we allow the effect to vary in one industry (printing and publishing) by adding an industry-specific reform variable to the vector of explanatory variables then we find a positive and significant coefficient of 0.041 (standard error: 0.024) for the term that aggregates over all U.K. monopoly cases. In fact, when we look across all policy reforms we find that their impact on entry (and on the entry-distance interaction) is very pronounced in some additional industries.

In the first-stage regressions in columns 5 and 6 we include a common EU-SMP effect across affected industries and allow for four additional industry-specific effects.[17] In columns 7 and 8 we use the U.K.-based policy reforms and allow the effects to vary in one industry affected by privatization and three industries with merger and monopoly investigations.[18] In columns 9 and 10 we include all of these instruments. For all first-stage regressions we report *F*-tests on the joint significance of the instruments excluded from the second-stage equations. Overall, the empirical evidence suggests that the set of EU-wide and U.K.-based policy reforms, which liberalized product markets and affected entry costs, have led to more greenfield foreign firm entry in the United Kingdom.

B. *Growth of Productivity*

We start by considering the average effect of entry on subsequent productivity growth in incumbents, and then focus on how entry effects vary with the distance to the technology frontier. All regressions in table 2 include year dummies and establishment effects. Standard errors allow for correlation between establishments within the same industry, and observations are weighted by employment and the inverse of their sampling probability.[19]

In columns 1 to 5 in table 2 we explain labor productivity (LP) growth in incumbents. In column 1 we show OLS estimates using the lagged levels of foreign entry, distance to frontier, import penetration, and competition as explanatory variables. We see a positive and significant correlation of greenfield foreign firm entry with subsequent LP growth in domestic incumbent establishments.[20] High values of the lagged distance measure indicate incumbent establishments in U.K. industries in years where they are far from their

[17] We include industry-specific reform variables for the following SIC-80 industries: 248 (refractory and ceramics), 361 (shipbuilding and repairing), 371 (precision instruments), and 432/438 (cotton and silk, carpets and other textile floor coverings).

[18] These SIC-80 industries are 2565 (explosive chemical products), 3204 (fabricated constructional steel work), 361 (shipbuilding and repairing), and 475 (printing and publishing).

[19] We find similar results if we estimate model specifications using unweighted data, four-digit industry instead of establishment effects, and standard errors that allow for correlation between establishments within the same industry-year. See table A.9 in the Web appendix.

[20] This is in line with related findings in Aghion et al. (2004), Griffith et al. (2002), and Haskel et al. (2007). The theory framework discussed above yields this prediction for plausible parameter assumptions (Web appendix, section 1.8).

industry-specific U.S. technology frontier. The positive and significant coefficient suggests higher LP growth rates for incumbents in industries far from the frontier. Another form of entry we control for is entry into local product markets through imports. We use a lagged measure of import penetration and find a positive and significant effect on subsequent LP growth in incumbents. To capture the variation of competitive conditions across industries and time, we include a lagged measure of average profitability in incumbents' industries. In line with previous work (such as Nickell, 1996), we find a positive and significant coefficient.[21]

Since our focus in this paper is on the variation of entry effects with the distance to the technology frontier, we now turn to more flexible empirical models where we interact foreign entry and distance to frontier (see equation [2] in section IIB). The OLS estimates in column 2 show a negative and significant coefficient on the interaction term, while the coefficients on the linear entry and distance terms remain positive and significant. The negative interaction effect counteracts the positive effect of entry in industries that are far away from the frontier.[22] Thus, the OLS results suggest that incumbent productivity growth responds more positively to technologically advanced entry in industries close to the technology frontier than in industries farther below the frontier.

In columns 3 to 5 we address the issue of entry endogeneity in the linear and in the interacted entry terms. We use alternative identification strategies with different sets of policy instruments as shown in table 1 and discussed above. In column 3 we use the set of EU-SMP policy instruments—the corresponding first-stage regressions are shown in columns 5 and 6 of table 1. In column 4 of table 2 we use the set of U.K. policy instruments, and in column 5 the full set of EU and U.K. policy reforms. The exclusion restrictions in these models are not rejected—the χ^2 test results are reported near the bottom of table 2. All three IV regressions show negative and significant interaction effects, and positive and significant linear effects and, thus, confirm the main conclusion from the OLS evidence.[23] Instrumenting is found to be important.[24] We find evidence for negative covariance between actual foreign entry and the error term in our productivity growth models in industries close to the frontier. This is in line with our expectation derived from theory. However, our findings are also consistent with attenuation bias towards 0 in OLS regressions, caused by measurement error.

So far we have focused on results for model specifications with growth in LP as the dependent variable. One concern with this might be that our results are affected by unaccounted for systematic variation in factor usage. In columns 6 to 10 of table 2 we reestimate using growth in total factor productivity (TFP) as dependent variable. The results and conclusions hold up, and the precision of the estimates tends to increase.

To investigate the economic significance of our estimates we calculate the growth impact of increasing entry by one sample standard deviation (0.5 percentage points) at the 10%, 50%, and 90% percentile of the sample distribution of the distance to the frontier, using the estimated coefficients from column 5. In industries at median distance, increasing greenfield foreign firm entry by one standard deviation raises subsequent LP growth in domestic incumbent establishments by 0.7 percentage points. In industries far from the frontier (90% percentile), the growth effect is -0.6 percentage points, and close to the frontier (10% percentile) it is 2 percentage points. Since the sample mean of incumbent growth in LP is 1.1% and the standard deviation is 13.8 percentage points, these estimates are economically significant and their variation along the distance distribution seems reasonable.[25]

All in all, the above OLS and IV estimates strongly indicate heterogeneity in the effects of greenfield foreign firm entry on subsequent LP and TFP growth of domestic incumbent establishments as predicted from theory: technologically advanced entry in industries close to the technology frontier triggers subsequent productivity growth among incumbents and can discourage it in industries that are far from the frontier.

C. *Patenting*

The evidence on productivity growth provides support for the idea that frontier entry spurs incumbents to invest in innovation, particularly when they are near the technology frontier. A lingering concern is, however, that productivity growth may reflect not only entry-induced innovative activity, but also entrant imitation or growth driven by realloca-

[21] The results in this paragraph all hold as well in models where we include each of the four explanatory variables separately. We checked that the coefficient of the entry rate is driven by changes in the numerator, the number of new employees in entering foreign firms, rather than by changes in the denominator. See table A.6 in the Web appendix.

[22] We find this pattern confirmed when we use a discretized model specification involving a different technology metric for measuring the distance to frontier (Web appendix, table A.7).

[23] Further variation of the set of policy instruments has also been investigated. When we restrict the set of instruments to either instruments capturing U.K. privatization cases only or U.K. merger and monopoly investigations only, we get qualitatively similar, but noisier second-stage results than those reported in table 2. However, in all these LP or TFP growth regressions the entry terms remain jointly significant at the 1% significance level. This is also the case if we restrict the instrument set to four variables that aggregate, respectively, EU-SMP industries, U.K. privatization cases, U.K. merger cases, and U.K. monopoly cases. In addition, both entry terms are then also individually significant in the TFP growth regression. See table A.8 in the Web appendix for further details.

[24] We can reject the null hypothesis of exogenous entry terms using F-tests on the control function: the F-test statistic for the LP model in table 2, column 5, is 3.07 with two degrees of freedom, and the one for the TFP model in table 2, column 10, is 7.92.

[25] Using the estimated coefficients from column 10 with total factor productivity gives more pronounced, but qualitatively similar, economic effects.

TABLE 3.—PATENT COUNTS: ZERO-INFLATED POISSON ESTIMATES

	(1) ZIP	(2) ZIP	(3) ZIP-CF	(4) ZIP-CF	(5) ZIP-CF
Dependent variable	Number of patents$_{ijt}$				
Foreign entry$_{jt-1}$ × distance$_{jt-1}$($E^F \times D$)		**−0.557**	**−1.933**	**−3.238**	**−1.665**
		(0.237)	*(0.679)*	*(1.618)*	*(0.583)*
Foreign entry$_{jt-1}$(E^F)	**0.107**	**0.245**	**0.608**	**0.437**	**0.506**
	(0.059)	*(0.078)*	*(0.227)*	*(0.216)*	*(0.171)*
Distance to frontier$_{jt-1}$(D)	**0.582**	**0.652**	**0.852**	**0.753**	**0.825**
	(0.250)	*(0.251)*	*(0.300)*	*(0.254)*	*(0.277)*
Import penetration$_{jt-1}$	**1.746**	**1.692**	**1.937**	**1.957**	**1.834**
	(0.817)	*(0.770)*	*(0.794)*	*(0.759)*	*(0.771)*
Import penetration$_{jt-1}$ squared	**−0.567**	**−0.542**	**−0.616**	**−0.605**	**−0.600**
	(0.309)	*(0.287)*	*(0.297)*	*(0.287)*	*(0.291)*
Competition$_{jt-1}$	**31.876**	**33.950**	**32.003**	**28.790**	**32.231**
	(16.764)	*(16.641)*	*(17.200)*	*(16.308)*	*(17.054)*
Competition$_{jt-1}$ squared	**−17.722**	**−18.885**	**−17.910**	**−15.733**	**−18.007**
	(9.413)	*(9.340)*	*(9.667)*	*(9.240)*	*(9.617)*
Patent stock$_{i,\ presample}$	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**
	(0.001)	*(0.001)*	*(0.001)*	*(0.001)*	*(0.001)*
D (patent stock$_{i,\ presample}$ > 0)	**1.490**	**1.502**	**1.515**	**1.503**	**1.515**
	(0.317)	*(0.318)*	*(0.319)*	*(0.316)*	*(0.317)*
Year effects	Yes	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes	Yes
			Inflation Equation		
Patent stock$_{i,\ presample}$	**−0.207**	**−0.207**	**−0.207**	**−0.207**	**−0.207**
	(0.037)	*(0.037)*	*(0.037)*	*(0.037)*	*(0.036)*
D (patent stock$_{i,\ presample}$ > 0)	**−0.558**	**−0.554**	**−0.550**	**−0.553**	**−0.552**
	(0.175)	*(0.175)*	*(0.175)*	*(0.175)*	*(0.175)*
Control function			E^F, $E^F \times D$	E^F, $E^F \times D$	E^F, $E^F \times D$
Type of instruments			SMP	MM, P	SMP, MM, P
Number of observations	1,073	1,073	1,073	1,073	1,073

Notes: The table displays zero-inflated Poisson estimates (ZIP) of patent count models; in columns 3 to 5 we allow for entry endogeneity in the linear and interacted entry term by including the respective first-stage residuals as control function terms. Estimates are for the sample of 1,073 observations on 174 incumbent firms listed at the London Stock Exchange between 1987 and 1993. Bold numbers indicate coefficients. Standard errors in parentheses and italics are robust and allow for correlation between firms within the same industry-year. 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.

tion between plants within incumbent establishments. To address this issue we explore the relation between entry and innovation more directly in patent count models. While we use a different data set, we find a strikingly similar pattern of entry effects as for productivity growth.

In table 3 we present estimates from a zero-inflated Poisson model.[26] For comparison we also show results for a linear model in column 9 of table 4 and for a generalized negative binomial model in column 10. All specifications in table 3 include year effects, dummies for (grouped) three-digit industries, and firm-specific presample patent stock variables to capture unobservable firm-specific, time-invariant heterogeneity of patenting behavior (see Blundell et al., 1999). We show sandwiched estimates of the standard errors, which allow for correlation between firms within the same industry-year. The probability of being granted zero patents is modeled as a function of a firm's presample stock of patents.[27]

[26] The firm panel that we use in this section provides industry information on the three-digit industry level only, whereas all estimations discussed so far involve using information on the four-digit industry level.

[27] When testing the inclusion of additional variables into the inflation equation, especially measures of entry, distance to frontier, trade, or competition, these turned out to be irrelevant.

In column 1 greenfield foreign firm entry and distance to the frontier enter in levels, while import penetration and competition enter as quadratic functions. Entry is positively correlated with the patenting activity of U.K. incumbent firms, as is distance to the technological frontier. For import penetration, the effects are increasing until above the 90% percentile of the sample distribution and positive for the whole distribution. We find an inverted-U relationship between competition and patent counts, in line with Aghion et al. (2005a).

In column 2 we include the interaction between foreign entry and distance to the frontier, and find this is negatively correlated with patenting in correspondence to our productivity growth results. In columns 3, 4, and 5 we allow for endogeneity of the linear and interaction terms by using the residuals from the first-stage regressions for entry and entry-distance interaction as control function corrections. As in table 2, we first show results using EU-SMP instruments only, then instruments reflecting the U.K. policy reforms only, and then using all these instruments together. The pattern of estimates holds across all three instrumenting strategies. Taken together, the patent count results suggest that a major driving force behind the entry effects in our productivity growth estimations is incumbent innovation, not just imitation or reallocation.

D. *Extensions and Further Robustness Checks*

Greenfield domestic firm entry and entry through imports. In our empirical analysis we focused so far on foreign firm entry, which is from firms that operate internationally, and are more likely to produce at the technological frontier than other entrants in the United Kingdom. This accords well with introducing entry threat at the new technological frontier into the framework of Aghion et al. (2001).

In that theoretical context, we can also explore the case where entry takes place behind the new frontier. If entry takes place one step behind the new frontier, then increasing entry threat encourages innovation and productivity growth in sectors that are at intermediate distance from the frontier; it discourages innovation and productivity growth in sectors that are far below the frontier; and it has little effect close to the frontier. In the case where entrants threaten to enter two or more steps behind the new frontier, no incumbent reactions are to be expected.[28]

In table 4 we show that greenfield domestic firm entry has no impact on incumbent LP growth (column 1) or patenting (column 5). The linear effects are insignificant, as are the interactions with the distance to frontier.[29] These results correspond with the predictions above, since greenfield domestic entry rates are likely to reflect entry behind the frontier. Typical findings in the literature are that the average domestic entrant struggles for survival during the first years after market entry, is occupied with learning about its own productivity and market conditions, and is very small compared with foreign entrants or incumbents in the same industry. The number of innovative domestic entrants is usually small, they are often found to be hampered by financial constraints or immature technologies and, thus, even innovative domestic entrants are unlikely to challenge incumbents shortly after their market entry.[30]

Entry through imports is another form of entry into product markets, and industry-level import penetration rates into the United Kingdom partly reflect entry of new products. Among these may be technologically advanced products, but also less advanced products. Our import penetration variable is, thus, a much noisier measure of frontier entry than greenfield foreign firm entry. In accordance with this we find similar, but weaker, effects for import penetration than for greenfield foreign firm entry. As already reported, linear (and quadratic) specifications for import penetration indicate positive and significant level effects. The coefficients of the interactions with the distance to frontier in our performance regressions are negative and significant in the LP growth and the patent count regressions (table 4, columns 2 and 6).[31] In all these regressions our main findings for the linear and interacted terms of greenfield foreign firm entry remain very stable.[32]

Endogeneity of distance to frontier, competition, and import penetration. We augment our main model specifications from table 2, column 5, and table 3, column 5, to allow for endogeneity of the distance to the technology frontier. We add the industry-level U.S. capital-labor ratio and the industry-level U.S. ratio of skilled over all workers to the set of instruments. These are significantly correlated with the distance measure and we assume that they do not depend directly on anticipated shocks to incumbent performance in the United Kingdom. We estimate three first-stage regressions: one for entry, one for the distance, and one for their interaction. The findings for LP growth and patenting in table 4, columns 3 and 7, show that our second-stage entry, distance, and interaction results remain robust.[33]

In addition, we test the robustness of our findings to allowing for endogeneity of import penetration or competition. When treating import penetration as potentially endogenous in the LP growth model we use the industry-level U.S. import penetration as an additional instrument and estimate three first-stage regressions: one for entry, one for the entry-distance interaction, and one for import penetration.[34] The second-stage results in table 4, column 4, provide support for a positive level effect of import penetration on labor productivity growth and, most important, for heterogeneous effects of greenfield foreign firm entry along the distance to the frontier distribution. These findings are confirmed in the corresponding patenting and TFP growth regressions.[35] To address potential endogeneity of our competition covariate, we add an industry-level index of U.S. profitability to the set of instruments, estimate the extended set of first-stage equations, and find our main results in LP growth, TFP growth, and patent count regressions again confirmed.[36]

[28] In this case actual entry would not occur since entry is optimal only when the entrant can take away market shares from the incumbent.

[29] The corresponding TFP growth regression confirms (Web appendix, table A.9).

[30] See, for example, Caves (1998), Disney, Haskel, and Heden (2003), Dunne, Roberts, and Samuelson (1988), Geroski (1995), and Gompers and Lerner (1999). In our data the average plant size of domestic entrants is about ten times smaller than that of foreign entrants in their industry and about seven times smaller than that of incumbent plants in their industry that are at least five years old.

[31] In the TFP growth regression we find a positive and insignificant coefficient for the import-distance interaction (Web appendix, table A.9).

[32] If we interact competition with the distance to frontier, these interactions remain insignificant in the LP growth, TFP growth, and patent count regressions. The estimates for the linear distance terms get noisy, but the coefficients for the entry terms and the entry-distance interactions remain stable and significant at the 1% or 5% significance level (Web appendix, table A.10).

[33] Results are similar if we use TFP growth as dependent variable (Web appendix, table A.9); first-stage results are in table A.5 in the Web appendix.

[34] See table A.5 in the Web appendix for first-stage results.

[35] See table 4, column 8 and table A.9 in the Web appendix.

[36] See table A.10 in the Web appendix.

TABLE 4.—ROBUSTNESS OF PRODUCTIVITY GROWTH AND PATENT COUNT RESULTS

	(1) IV	(2) IV	(3) IV	(4) IV	(5) ZIP-CF	(6) ZIP-CF	(7) ZIP-CF	(8) ZIP-CF	(9) OLS	(10) GNB
Dependent variable	Growth of labor productivity$_{ijt}$				Number of patents$_{ijt}$					
Foreign entry$_{jt-1}$ × distance$_{jt-1}$ ($E^F \times D$)	**−0.074**	**−0.052**	**−0.075**	**−0.098**	**−1.723**	**−1.438**	**−1.899**	**−1.664**	**−7.715**	**−0.546**
	(0.021)	*(0.023)*	*(0.019)*	*(0.026)*	*(0.558)*	*(0.552)*	*(0.861)*	*(0.593)*	*(3.675)*	*(0.285)*
Foreign entry$_{jt-1}$(F^F)	**0.028**	**0.022**	**0.020**	**0.032**	**0.514**	**0.410**	**0.475**	**0.501**	**3.206**	**0.296**
	(0.003)	*(0.005)*	*(0.009)*	*(0.004)*	*(0.168)*	*(0.170)*	*(0.208)*	*(0.172)*	*(1.497)*	*(0.082)*
Domestic entry$_{jt-1}$ × distance$_{jt-1}$	**0.003**				**0.137**					
	(0.005)				*(0.085)*					
Domestic entry$_{jt-1}$	**−0.002**				**0.004**					
	(0.002)				*(0.040)*					
Distance to frontier$_{jt-1}$ (D)	**0.087**	**0.166**	**0.231**	**0.092**	**0.721**	**2.278**	**1.127**	**0.785**	**8.181**	**1.294**
	(0.033)	*(0.047)*	*(0.104)*	*(0.028)*	*(0.322)*	*(0.811)*	*(0.480)*	*(0.273)*	*(2.575)*	*(0.327)*
Import$_{jt-1}$ × distance$_{jt-1}$		**−0.077**				**−1.117**				
		(0.035)				*(0.576)*				
Import penetration$_{jt-1}$ (*I*)	**0.084**	**0.085**	**0.067**	**0.201**	**1.823**	**1.825**	**1.664**	**1.807**	**5.509**	**1.558**
	(0.034)	*(0.034)*	*(0.033)*	*(0.073)*	*(0.820)*	*(0.740)*	*(0.803)*	*(0.781)*	*(5.816)*	*(0.794)*
Import$_{jt-1}$ squared					**−0.607**	**−0.531**	**−0.560**	**−0.650**	**−1.190**	**−0.452**
					(0.288)	*(0.276)*	*(0.291)*	*(0.306)*	*(1.937)*	*(0.321)*
Controls as in table 2	Yes	Yes	Yes	Yes						
Controls as in table 3					Yes	Yes	Yes	Yes		Yes
Inflation model as in table 3					Yes	Yes	Yes	Yes		
Competition and year controls as in table 3, firm effects									Yes	
Instrumented terms/Control function	E^F, $E^F \times D$	E^F, $E^F \times D$	E^F, $E^F \times D$, $\boldsymbol{D}$	E^F, $E^F \times D$, $\boldsymbol{I}$	E^F, $E^F \times D$	E^F, $E^F \times D$	E^F, $E^F \times D$, $\boldsymbol{D}$	E^F, $E^F \times D$, $\boldsymbol{I}$		
Type of instruments	SMP, MM, P	SMP, MM, P	SMP, MM, P, U.S. Input	SMP, MM, P, U.S. Import	SMP, MM, P	SMP, MM, P	SMP, MM, P, U.S. Input	SMP, MM, P, U.S. Import		
χ^2 test of overidentifying restrictions	13.18(10)	10.17(10)	8.81(11)	13.92(10)						
Number of observations	25,388	25,388	25,388	25,388	1,073	1,073	1,073	1,073	1,073	1,073

Notes: The table displays IV estimates of productivity growth models in columns 1, 2, 3, and 4, and OLS estimates of a patent count model in column 9. In these columns 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 terms are shown in columns 5, 6, 7, and 8; the inflation model is specified as in table 3. Column 10 provides results from a generalized negative binomial model without control function where the shape parameter alpha is specified as a function of firm-specific presample patent stock information. Standard errors in these columns are robust and allow for general 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. Input: industry-level U.S. capital-labor ratio and ratio of skilled over all workers; U.S. Import: industry-level U.S. import penetration.

Alternative omitted effects and knowledge spillovers as explanations. We investigate the possibility that the interaction between the distance to the technology frontier and foreign entry may simply reflect alternative omitted interaction effects. We expand the covariate vectors of our main model specifications with additional industry characteristics that might affect incumbents' abilities and incentives to react to entry. When adding, for example, a lagged industry-level measure of average establishment size and its interaction with entry to the labor productivity growth model we find similar effects for the linear entry term, the linear distance term, and their interaction as before.[37] Using instead the industry employment share in establishments with working owners to capture the variation of ownership structures across industries and time, or using an industry-level measure of capital per worker, does not lead to any instability of our main findings.

Finally, we consider the extent to which alternative theoretical explanations may also be consistent with the pattern of empirical results reported above. Potential candidates are theories that focus on the role of knowledge spillovers instead of innovation incentives. Consider the widely established idea that firms and sectors further from the technology frontier should benefit most from knowledge spillovers, since the scope for learning is highest there.[38] This suggests positive coefficients on the linear distance to frontier terms, as well as on their interactions with entry. We find, however, a different pattern, namely negative interaction effects and positive level effects of the distance to frontier.[39]

Another idea prevalent in the existing literature on knowledge spillovers argues that firms in industries closer to the technology frontier have higher absorptive capacity and may benefit more from spillovers. If so, then firms in industries closer to the frontier should react stronger to general spillovers, as well as to knowledge transfers from entrants, than firms in industries further behind the frontier. Our finding of negative and significant coefficients on the interaction terms is consistent with this. But the positive and significant coefficients for the linear distance to frontier terms are not in line with this explanation.

V. Conclusions

In this paper we provide comprehensive empirical evidence on substantial heterogeneity of productivity growth and patenting reactions in incumbent firms to foreign firm entry. This corresponds to Schumpeterian growth theory suggesting systematic variation of incumbent innovation incentives with the distance to the technology frontier. Threat of technologically advanced entry encourages incumbent innovation and productivity growth in sectors that are initially close to the technological frontier, whereas it may discourage incumbents in sectors further behind the frontier. We use rich micro panel data and address the problem of endogeneity in foreign entry by exploiting variation in entry conditions that arises due to major European or U.K. policy interventions. Endogeneity of distance to frontier, competition, and trade are also considered, and results for domestic firm entry and entry through import complement our analysis of foreign firm entry.

Our findings have implications for the policy debate on market (de)regulation, competition policy, privatization, and trade liberalization. This debate underlies the consideration of costs and benefits of globalization and the discussion on entry regulation in different countries and industries (Acemoglu et al., 2006; Bertrand & Kramarz, 2002; Djankov et al., 2002; Nicoletti & Scarpetta, 2003). Policies aiming at decreasing or removing product market barriers to entry alone may not be sufficient to foster growth of incumbent firms in all sectors of an economy, even if such policies are found to be growth-enhancing on average. This, in turn, suggests the need for complementary labor and capital market institutions that facilitate the reallocation of factors and resources from less to more technologically developed sectors where incumbent firms respond more positively to higher entry threat.

[37] Labor productivity growth regressions are shown in table A.11 in the Web appendix. Corresponding TFP growth or patent count regressions provide similar insights.

[38] Griffith et al. (2004) find empirical support for such consequences of general spillovers looking across a panel of OECD industries and countries. Griffith et al. (2002) find similar evidence at the establishment level in the United Kingdom.

[39] The theoretical framework we rely upon generates predictions in line with both these results (Web appendix, sections 1.4 and 1.7).

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