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The source of heterogeneous externalities: evidence from foreign multinationals in the UK

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ABSTRACT

The relationship between inward investments and local firms' productivity is contingent on several contextual conditions that collectively define the ability of firms and regions to recognise, assimilate and commercially apply external knowledge. Yet the empirical literature has been unable to account efficiently for such multidimensional sources of heterogeneous externalities. We introduce a novel two-stage empirical methodology that allows accounting for a wide range of moderating circumstances. Relying on a sample of 11,000 UK firms over the period 2012–2018, we show that while the nature of places affects the potential externalities from multinational enterprises (MNEs), what matters more are firm-level characteristics. This has important implications for regional policy, particularly in understanding the drivers of inequality, both within and across regions.

KEYWORDS

inward FDI; MNE investment; spillovers; productivity; mixed-effect models; heterogeneity

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1. INTRODUCTION

There is still a good deal of debate across various disciplines, including economic geography, regional studies and international business, concerning the drivers of regional productivity (e.g., Liu et al., 2023; Rodríguez-Pose & Ganau, 2022). A key debate that has run for some 30 years is whether attracting inward foreign direct investment (FDI) can help address the underlying causes of poor regional economic performance, or merely the symptoms. In other words, can it address low levels of productivity and innovation, or does it simply alleviate unemployment in the short term (Bajo-Rubio et al., 2010; Cook & Fallon, 2016; Pike et al., 2023)?

The process through which inward investment can generate externalities for the local economy has multiple stages (Driffield et al., 2010) based on knowledge transfer by the multinational and the capacity of local firms to appropriate such knowledge and translate it into productivity gains (Castellani & Zanfei, 2006; Meyer & Sinani, 2009).[1] Research on this topic has been particularly rich over the past decades and, while there is no consensus on the extent to which domestic firms benefit from inward investments, there is widespread agreement that these effects are contingent on several contextual factors.[2]

This paper addresses the heterogenous nature of externalities, by exploring the links between inward investment and host firm productivity, simultaneously allowing for a wide range of moderating factors at the level of the firm and of the region, that collectively define the ability of firms and regions to recognise, assimilate and commercially apply external knowledge. This enables us to build on the analysis offered by Frigon and Rigby (2022) on the sources of capabilities. For business and management scholars, capabilities reside within the firm, while for economic geographers capabilities are typically place-based, so we seek to address this distinction.

While the international business and regional studies literature have highlighted the importance of the characteristics of locations and the nature of the recipient firms in shaping the capacity to absorb externalities from multinational enterprises (MNEs), the relative contribution of place-based vs. firm-level capabilities in moderating the benefits from MNE-induced externalities have not yet been convincingly assessed. Using a novel empirical methodology, that enables us to simultaneously account for

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many sources of heterogeneity in the effects of MNE activity on the productivity of host country firms, we can fill this gap. This methodology relies on a two-stage approach whereby we first estimate a firm-level random parameter associated with the *extent of MNE externalities*, and subsequently explore the factors associated with such heterogeneous externalities by exploring variations of this parameter across firms.

Our research can shed light on a hitherto unresolved puzzle, that is vital for our understanding of the role that inward investment can play in fostering economic development: is this a firm-level problem or a regional-level problem? Specifically, are the links between attracting inward investment and generating productivity growth found at the level of the firm, through individual productivity, or at the level of the locality, through, for example, more general interactions and agglomeration effects?

This is vital for the efficacy of place-based policies and attempts to attract (and retain) MNEs to laggard and peripheral regions (Cui et al., 2020; Mudambi & Santangelo, 2016; Tang & Beer, 2022) to foster their catching-up. Through the lens of productivity, this has important implications for our understanding of regional inequality, whether expressed for example through the European Commission's Regional Cohesion policy or, in the case of the UK, 'levelling up' or 'inclusive growth'. It also helps us to understand the importance of firm-level capabilities in explaining regional growth, building for example on Newman et al. (2023) and McCann (2022).

Based on a sample of 11,000 UK manufacturing firms over the 2012–2018 period, we show, consistently with the existing literature, that the effect of MNE activity on host country firms is relatively small, and heterogeneous across firms and regions. Our results reveal that while the nature of place affects the potential externalities from MNEs, it explains only 1.8% of the variance in the effect of MNE activity on a firm's total factor productivity. Firm heterogeneity matters much more. Region, sector and year effects explain only 2% of the variation in gains from FDI, while firm characteristics explain an additional 12%. Further, adding firm productivity as a moderating factor further increases the adjusted R-squared by 3 percentage points to 17.1%. Among the regional characteristics, we find a significant negative moderating effect of the industrial specialisation and a positive effect on the degree of industrial diversity in the region. This result casts doubts on the widespread view that policies favouring the sectoral specialisation of regions and creating industrial clusters are conducive to more externalities from MNEs.

The paper is organised as follows: Section 2 delves into firm and regional characteristics as moderating factors for MNE-induced externalities. Section 3 outlines the empirical strategy. In Section 4, we present data and measures. Section 5 discusses the main findings and robustness checks, while Section 6 concludes, highlighting contributions to the literature and implications for regional policy.

2. THE EFFECTS OF FOREIGN MNEs ON THE LOCAL ECONOMIES. A FIRM LEVEL OR REGIONAL LEVEL PHENOMENON?

Typically, the approaches to understanding heterogeneity in the effects of MNEs are partial and often focus on characteristics that define the ability of firms or regions to recognise, assimilate and commercially apply external knowledge.

2.1. Spillovers at the level of the firm

As multinationals possess firm-specific advantages that often take the form of better technologies and managerial practices (Narula et al., 2019), in order to benefit from the presence of MNEs, local firms need to be able to first recognise the value of information brought by MNEs, and then, in turn, to disseminate within the organisation the information learned from multinationals, and to incorporate the new technology into their existing routines and processes (Cohen & Levinthal, 1990; Zahra & George, 2002). Not every firm possesses the capabilities to do so, hence the potential spillover from MNE is heterogeneous across local firms. The literature has suggested several firm characteristics that contribute to shaping a firm's capabilities to assimilate and commercially apply external knowledge. Several studies have focussed on firm innovation, human capital or productivity as factors capturing these capabilities, and the hypothesis has received wide empirical support (Ascani & Gagliardi, 2020; Békés et al., 2009; Blalock & Simon, 2009; Castellani & Zanfei, 2003; Girma, 2005; Liang, 2017; Ubeda & Pérez-Hernández, 2017; Zhang et al., 2010).

Other studies have delved more generally around the heterogeneity across host country firms into the extent of the benefits reaped from the presence of foreign MNEs. In a landmark study in this literature, Aitken and Harrison (1999) found that these benefits accrued mainly to local firms with some degree of foreign ownership. This is consistent with the idea that foreign-owned firms possess specific capabilities that enable them to assimilate and commercially apply external knowledge from other MNEs operating in the local economy. This finding is supported by Abraham et al. (2010), while Blomström and Sjöholm (1999) reveal that the degree of foreign ownership is not significantly associated with differences in spillovers.

The role of firm size as a moderating factor has received mixed support. On the one hand, it has been found that larger firms benefit more from MNEs (Aitken & Harrison, 1999; Békés et al., 2009) as these firms are better equipped to absorb the potential externality, but there is also evidence that spillovers may be larger for smaller firms as these firms have more opportunities for catching-up and learning from MNEs (Anwar & Sun, 2014; Damijan et al., 2013; Sinani & Meyer, 2004). Along similar lines, a few studies have investigated the moderating role of local firms' outward orientation (in terms of export and investments abroad), supporting the hypothesis that the effect of MNE activity is larger for domestically oriented firms (Abraham et al., 2010; Blomström & Sjöholm, 1999; Crescenzi et al., 2015; Sinani & Meyer, 2004).

2.2. Spillovers at the level of the region

A rich literature has investigated FDI spillovers at the regional level (Bournakis et al., 2019; Driffield, 2006; Stojčić and Orlić, 2020) and the extent to which the characteristics of regions moderate the benefits from inward FDI. A key argument in this literature is related to the regions' capability to decode and efficiently exploit new knowledge, whether this is locally produced or originating from outside (Caragliu & Nijkamp, 2016). In keeping with this, several studies have found that the effect of inward FDI on regional innovation and productivity is positively moderated by investments in R&D, the quality of human capital and the productivity of the host regions (Bournakis et al., 2019; Fu, 2008; Smith & Thomas, 2017).

The literature that seeks to explore the potential gains from inward investment at the level of the region, emphasises the importance of the make-up of local industry, co-location and agglomeration. Such approaches see inward investors as becoming part of the local ecosystem, and mutually boosting innovation, productivity and the demand for skilled labour. In this perspective, more specialised regions may be more vulnerable to locking into their areas of expertise due to their specialisation being less compatible with foreign technologies than it is for the more diversified regions. Indeed, the more diversified regions may have a broader knowledge base, which plays a crucial role in absorbing technology spillovers from foreign MNEs (Beaudry & Schiffauerova, 2009). Rutten (2019) argues that diversification is positively linked to productivity, while a more specialised region can foster learning and sharing of knowledge through the development of similar technological languages, attitudes, routines and interpretative schemes (Maskell & Malmberg, 1999). Ning et al. (2016) find evidence that a more specialised industrial structure promoted FDI spillovers in a particular city. Their argument highlights that highly specialised knowledge bases can facilitate the absorption of knowledge embedded in FDI. Furthermore, regional industrial specialisation can generate local pecuniary linkages and a concentration of resources (Beaudry & Schiffauerova, 2009), leading to increased transactions between indigenous and foreign firms.

The local industrial nomenclature is important here. While there is a large literature that focuses on clusters, and other sources of agglomeration economies, they often ignore what such concentrations mean for local labour markets, and especially skill shortages. High levels of specialisation may be associated with a high demand for specialised labour, which often outstrips supply. Illustrating this, Becker et al. (2020) emphasise the role that labour market tightness plays in limiting the likely employment or productivity gains from attracting inward investment. This is explored in detail by Hervas-Oliver et al. (2022) who highlight the tension that inward investors have between becoming embedded in the local economy, and at the same time needing to 'poach' the best workers from other firms. Local industrial strategies can actively encourage regions to take a sector-based approach, focussing on increasing industrial specialisation on their existing strengths (Bailey et al., 2021), but this has the side effects of tight labour markets locally and an increase in demand for particular types of labour (Peters, 2020). As Becker et al. (2020) show, attracting inward investment in such regions can compound this and choke off many of the potential gains.

3. EMPIRICAL STRATEGY

The extensive research that we have briefly reviewed in the previous section has highlighted several dimensions that affect the capacity to benefit from potential MNE-induced externalities. Some of these operate at the level of the firm, while others are exogenous to it, characterising the local context in which the firm is embedded. These two levels of analysis are both potentially relevant but current research is unable to provide insights on their relative importance.

When accounting for different moderating factors, the most commonly adopted solution is to interact the explanatory variable with the relevant moderating variable (Chung & Alcácer, 2002). This can easily create estimation problems because when one attempts to incorporate a large number of interactions the risks of multicollinearity and imprecise estimates increase. An alternative solution is to run sub-sample analyses based on critical values of the moderating factors (Ascani & Gagliardi, 2020). This approach has the merit of overlapping different dimensions at more than one level of analysis but it presents the challenge of defining a somewhat arbitrary choice of threshold levels. Also, running sub-sample analysis can reduce the precision of estimates due to small sample sizes and the difficulty of testing for the statistical significance of differences across samples (Girma, 2005; Hansen, 2000). Furthermore, and highly pertinent to this research, this approach does not offer insight into the extent to which each dimension helps explain the heterogenous effect of FDI. In what follows, we will illustrate a novel methodology that could help address the shortcomings in the existing literature.

3.1. Two-stage random parameter model

Our estimation strategy must allow us to (1) assess the effect of the foreign presence on the productivity of firms located in the same region, and account for the possibility that such foreign exposure can have a heterogeneous effect across firms and regions and (2) investigate the multiple sources of such heterogeneity and assess their relative explanatory power.

We approach this estimation problem with a two-step econometric strategy (Hornstein & Greene, 2012).

3.1.1. First step: random parameter (mixed-effect) model

In the first step, we estimate a random parameter (mixed-effect) model (RPM) of the effect of the foreign presence in a region on the productivity of each firm located in the same region. RPMs represent an appealing method for going beyond average effects to explicitly model heterogeneity, something that standard regression models cannot do directly (Alcácer et al., 2018). RPMs are a special case of multilevel (also called hierarchical or mixed-effect) linear models, particularly popular when data have a hierarchical structure with more than one level; in other words, when the focal (lower-level) units are nested within higher-level units (Hofmann, 1997). An RPM can be seen as a single-level hierarchical model, where the level is the individual or the firm. In the case of longitudinal data like ours, the literature on this class of models suggests the data should be treated as a two-level structure, where the first level of the hierarchy is the different measurement occasions over time t of the dependent variable for each firm throughout the period, representing our observations. Then, observations are nested within firms – the second level of the structure – and time should enter the model as a continuous variable and also as a possible source of randomness (Hedeker & Gibbons, 2006). RPMs are characterised by some peculiar features. While in a standard regression, the coefficient of an explanatory variable (e.g., the foreign presence in a region) is assumed to be constant across observations (e.g., firms), an RPM allows the coefficient to vary by subject, returning two statistical moments. These are (i) the mean, the average effect common to all the subjects and (ii) the standard deviation, the deviation from the average effect of each subject. When the standard deviation is statistically different from zero, a component of heterogeneity does exist, and it can become more informative than the average coefficient. The simplest case is when the intercept (the constant) is allowed to vary across firms; this returns results similar to traditional random effects (RE) models.

Considering a linear regression model formalised as follows:

$$Y_{irst} = \alpha_i + \beta F_{rt-1} + \theta_1 X_{1rt-1} + \theta_2 X_{2it-1} + \delta t + \eta_s + \lambda_r + \varepsilon_{irst} \quad (1)$$

where Y_{irst} is the productivity of firm i at time t, F is a measure of the activity of foreign-owned firms (or inward FDI) in region r at time t-1, and X_{1rt-1} and X_{2it-1} are a set of time varying location and firm characteristics. η and λ are industry and region fixed effects, while t denotes a time trend. We can allow for differential intercepts at the firm level (α_i), whereas β, θ_1 and θ_2 are fixed coefficients equal for all firms. The coefficient α_i can be expressed as:

$$\alpha_i = \gamma_{00} + u_{i0} \quad (2)$$

Where γ_{00} is the overall mean, and u_{i0} is the random part of the model consisting of higher-level residuals. In other words, u_{i0} is the distance from the sample mean ascribed to the firm-level group i.

The specification in (1) and (2) assumes homogeneous effects associated with the predictors, but this can hide heterogeneous behaviours across firms. An additional step explicitly models such heterogeneity, allowing for randomness not only in the intercept but also in the slope of some explanatory variables. It estimates firm-specific parameters that capture the individual response to our variables of interest; in our case, this is the presence of foreign-owned firms in a given region. Thus, the parameter β associated with variable F_{rt-1} in (1) can be set as random at the firm level, and the model can be formally extended as follows:

$$Y_{irst} = \gamma_{00} + u_{i0} + \beta_i F_{rt-1} + \theta_1 X_{1rt-1} + \theta_2 X_{2it-1} + \delta t + \eta_s + \lambda_r + \varepsilon_{irst} \quad (3)$$

where

$$\beta_i F_{rt-1} = \beta_0 F_{rt-1} + u_i F_{rt-1} \quad (4)$$

here, β_0 is the overall mean slope and u_i is the slope deviation for firm i for the variable F_{rt-1}. This specification differs from (1) as in (3) β is allowed to vary across firms. Thus, β_i varies in the population with a probability density function g(.)[3], decomposed in its mean coefficient (β_0) common to all firms and a standard deviation (σ). In other words, considering Equation (4), u_i is the deviation from the mean coefficient β associated with firm i, randomly distributed with mean zero and standard deviation σ. A significant σ reveals that different firms may have significantly different benefits from their exposure to the activity of foreign multinationals (FDI spillovers).

3.1.2. Second step: using random parameters as dependent variables

A significant standard deviation σ of the random parameters of our variable of interest F informs us that a component of heterogeneity in firm behaviour exists. In these cases, RPMs allow us to estimate firm-level coefficients ($\hat{\beta}_i$), by predicting the firm-specific random component u_i, which captures the individual response of a specific variable of interest. Then, this vector can be used as a dependent variable in a second-stage regression, where several factors can enter the model simultaneously to explain its variation across firms (Alcácer et al., 2018; Castellani & Lavoratori, 2020; Greene et al., 2009; Lavoratori & Castellani, 2021). More formally,

$$\hat{\beta}_{irs} = \alpha + \pi_1 Z_{1i} + \pi_2 \lambda_r + \pi_3 \eta_s + u_{irs} \quad (5)$$

where $\hat{\beta}_{irs}$ is the vector of predicted firm-specific coefficients and Z_{1i} is a vector of firm-level covariates.[4] By introducing a vector of region (λ_r) and industry (η_s) fixed effects we can appreciate the relative contribution of firm, industry and region characteristics to explain the extent to which different firms benefit from the activity of MNEs in the local economy.

$$\hat{\beta}_{irs} = \alpha + \pi_1 Z_{1i} + \pi_2 Z_{2r} + \pi_3 \eta_s + u_{irs} \quad (6)$$

In order to appreciate the role of specific regional characteristics, we estimate Equation (6) as a variant of Equation (5) where region fixed effects are replaced with a vector of region-specific covariates. It is worth noting that this approach *simultaneously* controls for many moderating factors and threshold effects, including a whole range of region and sector fixed effects. Previous studies, relying on interaction effects or subsample analysis, have typically chosen to select a few of these moderating conditions. To make a concrete example, it is well known that the opportunity for externalities may differ across sectors. Among others, Ascani et al. (2022) show that inward FDI have a stronger effect on local innovation in science based than in specialised supplier industries. Our study is not explicitly interested in the role of sectoral characteristics as moderating factors, but we do not want to confound this effect with other moderating factors, such as innovation and firm size, that can also differ across sectors. Our methodology can easily accommodate this, unlike prior studies relying on interaction effects and sub-sample analysis.

Saxonhouse (1976) and Hornstein and Greene (2012) suggest that the estimated parameters may suffer from heteroscedasticity, which can lead to inefficient second-stage estimates. To address this issue, in the first stage along with the coefficient of interest for each firm, we obtain the standard error of each estimate. These estimated standard errors are then used as weights for the second-stage regression.

4. DATA AND MEASURES

4.1. Data

Our empirical analysis is based on firm-level information in the United Kingdom throughout 2012–2018. Data are gathered from Fame, a database provided by Bureau van Dijk (BvD), a Moody's Analytics Company, which collects firm-level data from profit and loss balance sheet accounts.

The database contains 104,806 firms, operating in 87 sectors (following the NACE Rev.2 classification, at 2-digit level from NACE 01 to NACE 99). For our analysis, we rely on the sample of manufacturing firms comprising 10,828 firms operating in 23 2-digit manufacturing sectors (NACE Rev.2 10–32[5]). However, we use the total sample for computing the measures of a foreign presence in the region. We classify the companies by size relying on balance sheet information; thus, large firms have a balance sheet greater than EUR 43 million, while medium and small enterprises do not exceed EUR 10 and 2 million, respectively (OECD, 2005, p. 17). Small firms represent 57% of the sample, 27% are medium, and the remaining 16% are large firms.

We refer to the NUTS-3 regions as our geographical unit of analysis. The NUTS (nomenclature of units for territorial statistics) classification is a hierarchical system developed by Eurostat for dividing territories of the EU countries and the UK (Eurostat, 2018), with the NUTS-3 level being the more granular level of analysis. We rely on the 2010 NUTS classification to maximise the availability of data over the period of our analysis. According to this classification, the UK has 12 regions at the NUTS-1 level (which corresponds to the regions, e.g., West Midlands, East of England, London, Wales, Scotland, Northern Ireland, etc.), and 37 and 139 regions at the NUTS-2 and 3 levels, respectively. We assign each firm to its corresponding NUTS-3 using postcode information. As an alternative geographic unit of analysis, we repeat our analysis using travel-to-work areas (TTWAs), to check whether our results are sensitive to the geographical boundaries adopted.

4.2. Variable definition

4.2.1. First-stage model specification

Dependent variable. In the first stage of our empirical analysis, we estimate the effect of the foreign presence on the firm's total factor productivity (TFP). In doing so, we compute the TFP as the residual of a standard Cobb–Douglas production function which is allowed to vary by industry, more formally:

$$\log(T\hat{F}P_{it}) = ln\, Y_{it} - \hat{\beta}^k \ln K_{it} - \hat{\beta}^l \ln L_{it}$$

where i and t refer to firm and time, respectively. Y is the firm output measured as total revenue. We also use the value added as a robustness check, calculated as total sales (turnover) minus costs of materials and inventories (costs of sales). K and L represent the production inputs. K is the capital stock computed using the book value of fixed assets reported in Fame. We deflate the fixed assets and material costs with material and capital assets deflators respectively; these are provided by the Office for National Statistics (ONS). We convert the sales into real values using a production price deflator (also provided by the ONS) where 2010 = 100. We measure labour L by the number of employees of the company. All variables are transformed in natural logarithms.

To estimate the parameters of the production function (β^k and β^l), we use a robust one-step estimation procedure implementing a generalised method of moments approach proposed by Wooldridge (2009) (TFP_WRDG).[6]

Main independent variable: presence of MNEs. We measure the presence of foreign MNEs as the total assets of foreign-controlled companies in the region. We define a company as foreign-owned applying the stringent criteria proposed by Merlevede et al. (2015), which are based on the OECD and IMF definitions and rely on shareholder links (direct shareholder % and total shareholder % if the former is missing). Foreign ownership requires that (1) shareholders have a known nationality that is different from the host country nationality – in our case the UK – and if the country is not known, the owner is deemed to be domestic; (2) at least 10% of shares are owned by a single foreign shareholder and (3) more than 50% of shares are foreign-controlled. We collect information on direct shareholder and total shareholder ownership shares in every year (2011–2018) from the Fame database. This allows us to create a foreign ownership variable that can change over time throughout the period of the study. As suggested by Castellani and Zanfei (2003), we do not express foreign assets as a share of total assets. Rather, we include the logarithmic transformation of the absolute value, alongside the log of total assets of domestic firms. This allows for a more flexible specification that avoids potential biases in the estimation of a foreign presence ratio (Castellani & Zanfei, 2007).

We also include a set of widely used firm-level control variables, such as firm age, size and a dummy for foreign-owned firms, along with industry, year and regional fixed effects. Explanatory variables are lagged by one year (t-1).

4.2.2. Second-stage model specification

Extent of MNE externalities ($\hat{\beta}_i$). Given the purpose of our study and the two-stage empirical design as discussed in the methodology section, we predict individual-level parameters ($\hat{\beta}_i$) associated with the effect of a foreign presence on firm productivity from the first stage,[7] which we use as a dependent variable in the second stage. In so doing, we have one value for each firm in the sample because this is a constant attribute of the firm. The values in this vector, provide information on the effect of MNE activities in a region on each firm in that region.

As discussed in Section 2 and illustrated in Equations (5) and (6), several sources of heterogeneity can operate simultaneously at different levels of analysis. This paper is interested mainly in firm- and region-level characteristics affecting the ability of firms to reap the potential benefits of MNE-induced externalities. We approach this by first regressing $\hat{\beta}_i$ on regional fixed effects. As discussed in Section 3, while the moderating role of industry conditions is not of direct interest to this paper, we exploit the flexibility allowed by our methodology to include industry-fixed effects for completeness. This allows us to gauge the extent to which regional and industry characteristics drive heterogeneity in FDI spillovers. Then, we add firm-level variables to capture the heterogeneity of a firm's ability to both generate and assimilate knowledge and we assess their contribution to explaining the variation of $\hat{\beta}_i$ across firms. Finally, we substitute region-fixed effects with regional characteristics to identify the moderating role of specific territorial characteristics that bear particular interest for regional policy.

We include in our second-stage regression several firm-level characteristics that, according to the literature, may correlate with the extent of MNE externalities ($\hat{\beta}_i$).

First, we look at *innovation* as a factor able to increase the ability of the firm to extract value from the presence of the MNEs (Zou et al., 2018; Harris and Yan, 2019). We collect patent data at the firm level from Bureau van Dijk's Amadeus, and we compute the cumulated number of patents as an additional firm-level characteristic and an additional measure of absorptive capacity. In detail, we were able to identify 27% (2873 out of 10,828) of patenting firms, and we assumed that firms not in Amadeus Patents do not have patents. We collected information on the patent applications, publication number and date, to measure the innovation activities of each firm. Each patent is divided equally among all companies (fractional counting) in the case of multiple assignees. We expect that higher innovation output is positively correlated with the ability of firms to benefit from potential MNE externalities.

Second, we control for the *size* of each local company by creating two dummy variables that assume a value of one if the companies are respectively classified as medium or large according to the definitions discussed above. We expect that larger firms have a higher ability to benefit from FDI (Aitken & Harrison, 1999; Békés et al., 2009), but there is also a view that MNE externalities may be larger for smaller firms as these firms have more opportunities for catching-up and learning from MNEs (Anwar & Sun, 2014; Damijan et al., 2013; Sinani & Meyer, 2004).

Third, firm *age,* which is computed as the logarithm of the difference between the year of incorporation and t_0, that is the first year the firm appears in the sample, is expected to positively correlate with the extent of MNE externalities, as older firms accumulate experience that enables them to recognise and assimilate knowledge (Coad, 2018). However, some studies have found a negative moderating effect of firm age. As we argued for firm size, younger firms may have more opportunities for catching up and learning from MNEs (Anwar & Sun, 2014).

Fourth, *foreign ownership,* measured by a dummy variable taking a value of one if the firm is foreign-owned, is expected to positively correlate with the ability to absorb external knowledge, especially when this comes from other MNEs (Abraham et al., 2010; Aitken & Harrison, 1999). To compute this dummy, we use information on the nationality of the shareholders and their shares from Fame, as discussed in Section 4.2.1.

Fifth, we also control for the outward orientation of the firm, typically found to be positively correlated with productivity (Henley & Song, 2020). We measure experience in two ways: (1) *depth of multinationality* as the number of foreign subsidiaries divided by the number of total subsidiaries and (2) *breadth of multinationality* as the number of countries where a firm has foreign subsidiaries (Castellani et al., 2017; Kafouros et al., 2012). The information on the number of foreign subsidiaries and their locations is gathered from Fame. Previous studies have found that the extent of MNE externality is larger for domestically oriented firms. The main arguments revolve around the lower catching-up opportunities for the more outward-oriented firms and the lower need to rely on foreign MNEs knowledge (Abraham et al., 2010; Blomström & Sjöholm, 1999; Crescenzi et al., 2015; Sinani & Meyer, 2004).

Sixth, we control for the *capital intensity,* as the ratio between capital (fixed assets) and labour (number of employees), and its performance, calculated as the ratio between net income and total assets (*ROA return on assets*). Data are collected from Fame.

Finally, we follow a consolidated literature, discussed in Section 2.1, that has used *productivity* as a moderating factor for the extent of MNE externalities (see for example Castellani & Zanfei, 2003; Girma, 2005). In the context of our analysis, the reader might be worried about a potential mechanical relationship because productivity serves as the dependent variable in the initial stage. Acknowledging these concerns, we treat this as an additional analysis. Additionally, in the second stage, we replace TFP, the dependent variable in the first stage, with labour productivity – calculated as the natural logarithm of total revenue per employee.

As illustrated in Equation (5), along with firm-specific characteristics, we capture region-level heterogeneity in the ability of regions to benefit from FDI by including region fixed effect (at the NUTS-3 level) in our second-stage regressions. In order to identify the role of specific region and region industry characteristics we also estimate our second stage model by replacing such fixed effects with the following variables. We first measure the *innovation activity* of the region by calculating the stock of patent applications to the European Patent Office, by priority year over the period 2000–2012, as a share of total employment in the region. The number of patent applications and employees are available from Eurostat at the NUTS-3 level. Furthermore, we control for the *aggregate regional productivity*, as measured by gross value added (GVA) per employee of the region, provided by Eurostat at the NUTS-3 level.

As discussed in Section 2, the industrial structure of a region is also an important component of the ability of firms in the region to absorb spillovers from foreign MNEs. We compute (i) the *specialisation index* as the share of industry employment in region *r* relative to the share of the industry in overall UK employment (Glaeser et al., 1992) and (ii) the *industrial diversity* index as an inverse Herfindahl index of the relative employment distribution across industries in region *r*. We compute the Herfindahl index as the sum of employment in industries other than s (sector of the focal firm) as a share of the total

Table 1. List of Variables.

Variable	Description	Type
TFP_WRDG	Total factor productivity (log) of firm i at time t, using the Wooldridge (2009) estimation procedure	Firm
Foreign Assets	Total foreign-owned assets (log), at time t-1	NUTS-3
Domestic Assets	Total domestic-owned assets (log), at time t-1	NUTS-3
Age	Firm Age (log), at time t-1	Firm
Foreign-owned	Dummy = 1 if the firm is foreign-owned, namely if (1) foreign owners have a known nationality, different from the host country nationality (UK); (2) at least 10% of shares are owned by a single foreign investor and (3) more that 50% of shares is foreign-controlled, at time t-1	Firm
Firm size: Small	Dummy = 1 if the firm balance sheet does not exceed 2 million EUR	Firm
Firm size: Medium	Dummy = 1 if the firm balance sheet does not exceed 10 million EUR	Firm
Firm size: Large	Dummy = 1 if the firm balance sheet is greater than 43 million EUR	Firm
No. of patents	Cumulated fractional count of the number of patents owned by the firm (log), at time t-1	Firm
Labour productivity	Labour productivity is measured as total revenue per employee (log), at time t-1	Firm
ROA	Return on assets calculated by dividing the firm's net income by its total assets, at time t-1	Firm
Share foreign subsidiaries	Ratio of foreign subsidiaries to the total number of subsidiaries, at time t-1	Firm
No. of foreign countries	No. of countries where foreign subsidiaries are located (log)	Firm
K/L ratio	Ratio between capital (fixed assets) and labour (number of employees) (log), at time t-1	Firm
GVA per employee	GVA per employee (log), from Eurostat	NUTS-3
Patents per employee	Stock of patent applications to the EPO by priority year and NUTS 3 regions, over the period 2000–2012	NUTS-3
Specialisation Index	Share of industry employment in the area, relative to the share of the whole industry in the UK employment, at time t-1	NUTS-3/NACE 2-digit code
Industry diversity	Inverse Herfindahl index of the sum of employment in each industry other than s sector of the focal firm as a share of the total employment in industries different than s, at time t-1	NUTS-3/NACE 2-digit code

employment in industries different than s, where higher values of diversity correspond to greater industrial diversity (Martin et al., 2011).

Detailed definitions of all variables are reported in Table 1, while descriptive statistics and correlations of first-stage and second-stage variables are reported in Tables A.1 and A.2 in the Appendix in the supplemental online data. All explanatory variables of the second stage are calculated at the beginning of the observation period for each firm. In other words, based on the first-stage model, the year in which the firm first appears in the sample.

5. RESULTS

5.1. Estimating the determinants of firm-level TFP (first-stage)

Results from our first-stage multilevel (mixed-effect) estimation show that, on average, the presence of foreign investments in the region positively affects the productivity of firms in the same region (TFP) (Table 2, Mod. 1a). These results are confirmed when we estimate our baseline using a firm fixed effect (FE) model relying on a within-group estimator, and a random effect (RE) model using a maximum likelihood random-effects estimator (Mods. 1b and 1c). The magnitude of this effect is small: in the best-case scenario (the FE-WG estimates) a 10% increase in the total assets of foreign-owned firms is associated with a 0.93% increase in the TFP of firms within the same region. Table 2 also reveals that firm productivity is positively associated with age (suggesting learning effects), firm size and foreign ownership.

A key result of our first-stage analysis is that the average small positive spillover effect from foreign MNEs is indeed quite heterogeneous. Once we extend Mod. 1a to allow for randomness at the firm level in the slope associated with the *foreign assets* variable, the average (mean) coefficient of *foreign assets* turns out to be not significant; however, a significant standard deviation highlights the presence of heterogenous firm productivity returns from the presence of MNEs in the region, as shown by Mod. 2 (Table 2). In the next sub-section, we will explore this heterogeneity in more detail, focusing on Mod. 2 as our preferred model.

5.2. Explaining the heterogeneity in the effect of foreign presence on firm productivity (second-stage)

In Figure 1 we plot the kernel density distribution of the vector of predicted firm-level parameters from Mod. 2 in Table 2. The distribution is highly concentrated around zero and with a rather large variance, which is consistent with the presence of heterogeneous effects.

These differences are explored more systematically in Table 3, where we use the vector of the predicted firm-level parameter $\hat{\beta}_i$ as the dependent variable in a second-stage ordinary least squares (OLS) regression, as per Equations (5) and (6).[8] Starting with Mod. 1 in Table 3, we estimate Equation (5) by simply regressing the vector of predicted $\hat{\beta}_i$ parameters on region and year fixed-effects. This model explains a mere 1.78% of the variance in MNE-induced externalities. Adding industry fixed effects leads the adjusted R-squared up by 0.3 percentage points (to 2.1%, Mod. 3). Adding firm characteristics seems to improve the fit of the model significantly. In particular, in Mod. 4 we include firm age, a dummy that identifies foreign-owned firms, capital-labour ratio, ROA, multinational depth and breadth, number of patents and two dummies for medium and large firms[9] (small firms as the baseline). The adjusted R-squared increases about sixfold to 13.8%. Furthermore, Mod. 5 reveals that productivity plays an important role in determining the extent of the potential effect from the activity of foreign MNEs. The adjusted R-squared increases further to 17%. All in all, these findings suggest that while firms located in different regions benefit differently from MNE externalities, the largest heterogeneity is observed across firms within regions (and sectors). This is part of a common thread within research on regional disparity (McCann & Yuan, 2022) that while some locations have on average lower productivity than others, one finds frontier firms everywhere, but also that one finds heterogeneity in productivity across relatively short distances (Driffield, 2022). One can say the same therefore regarding the gains in productivity from inward investment. Improving the contextual conditions, such as fostering clusters, encouraging agglomeration, or sector-based interventions on innovation or skills, in the region may lead to an increase in the capacity of local firms to benefit from the presence of foreign MNEs in the regions. However, this contribution is an order of magnitude lower than what can be achieved with improvements at the firm level and is unlikely to benefit lagging firms.

Among the most important factors that affect the extent of MNEs externalities, we find the level of innovation, firm size, profitability and multinational breadth of local firms. These results are consistent with the idea that innovation, performance and internationalisation contribute to defining the ability of a firm to assimilate external knowledge from MNEs. This is confirmed in Mod. 5, where labour productivity displays a strong positive association with the extent of MNE externalities. In Mod. 4 we notice that foreign-owned firms do not benefit more than average from the presence of other MNEs. However, when we control for productivity in Mod. 5 and 7, results suggest that for domestic-owned firms the externalities from MNEs are higher. It is worth noting however that foreign ownership appears to positively moderate the extent to which a firm benefits from other MNE activity, but only if we do not control firm size or productivity. This would suggest that foreign-owned firms benefit more, but this is because they are larger and more productive, rather than because they are foreign. This result allows us to appreciate how important it is to simultaneously account for several sources of heterogeneity, and how an approach like ours can uncover this kind of result.

Table 2. Estimating FDI spillovers on productivity, using random parameter models (RPMs).

	Mod. 1a		Mod. 1b	Mod. 1c	Mod. 2	
Estimation method	**ME-RC**		**FE-WG**	**RE**	**ME-RS**	
DV: TFP_WRDG	**Mean**	**Std. dev**	**Mean**	**Mean**	**Mean**	**Std. dev**
Foreign assets	0.0072**		0.0093**	0.0059	0.0002	0.1504***
	(0.0035)		(0.0045)	(0.0044)	(0.0046)	(0.0048)
Domestic assets	0.0180**		0.0186*	0.0174*	0.0206**	
	(0.0080)		(0.0109)	(0.0108)	(0.0084)	
Foreign-owned	0.0220***		0.1125***	0.0717***	0.0222***	
	(0.0063)		(0.0185)	(0.0094)	(0.0063)	
Age	0.0826***		−0.0008	0.0342***	0.0753***	
	(0.0071)		(0.0089)	(0.0083)	(0.0070)	
Firm size: medium	0.2718***		0.1829***	0.3253***	0.2719***	
	(0.0052)		(0.0102)	(0.0095)	(0.0052)	
Firm size: large	0.6271***		0.3627***	0.7856***	0.6243***	
	(0.0096)		(0.0203)	(0.0194)	(0.0096)	
Year (time trend)	−0.0004		0.0018	−0.002	−0.0003	
	(0.0010)		(0.0018)	(0.0016)	(0.0011)	
Constant	16.2482***	0.8921***	11.0416***	19.6188***	16.1798***	3.2740***
	(1.9217)	(0.0066)	(3.3703)	(3.0790)	(1.9672)	(0.1131)
Industry fixed effects (NACE 2-digit code)	yes		yes	yes	yes	
Regional fixed effects (NUTS-3)	yes		yes	yes	yes	
Random effect parameters						
Firm individual level						
Corr (Foreign Assets; cons)					−0.9697***	
					(0.0021)	
Std dev (Residual, Total)	0.2687***				0.2623***	
	(0.0009)				(0.0009)	
Log likelihood	−27983.602				−27579.402	
Number of observations	59693		59693	59693	59693	
R-sq within			0.049	0.043		
R-sq overall			0.282	0.489		
R-sq between			0.282	0.488		

Note: The dependent variable is the total factor productivity of firm I at time t. Standard errors in parenthesis below point estimates. Asterisks denote confidence levels: *$p < 0.10$, **$p < 0.05$ and ***$p < 0.01$.
Estimation methods: mixed effect model with random constant (ME-RC), fixed-effects within-group model (FE-WG), random-effects model (RE), mixed-effect with random slope parameters (ME-RS).
The mixed effects models are estimated using the 'mixed' package (StataCorp, 2013) in Stata 14 and 16, with the covariance (unstructured) option which allows for all variances and covariances to be distinct, and the correlation between random slopes and intercepts ('Corr'). The 'Std dev (Residual, Total)' reports the estimated variance of the overall error term.

The negative coefficient associated with firm age suggests that, *ceteris paribus*, younger firms benefit more from MNE externalities. This result suggests that MNEs may be important breeding grounds for high-level employees who can feed start-ups with the human capital they require to improve their productivity and is consistent with Andersson et al. (2022).

Our results also highlight the nature of the interaction between firm size and firm capital intensity in explaining spillovers, and again confirm the importance of being able to control for several moderating factors at the same time. Independently, both effects are positive,[10] but together, when we control for firm size, capital intensity has a negative moderating effect. In other words, once

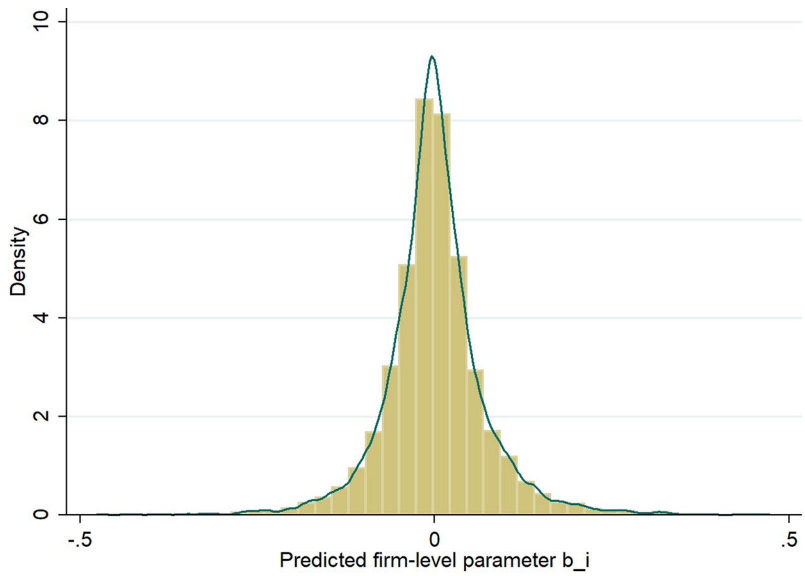

Figure 1. Kernel density distribution of predicted firm-level parameter $\hat{\beta}_i$
Note: authors' elaboration from stage-one results from mod.2, Table 2.

we control for firm size, less capital-intensive firms benefit more from MNE externalities. This is consistent with the idea that a key benefit from the presence of MNE is related to the possibility of imitating managerial practices that improve the productivity of workers in local firms (Bloom et al., 2019), and the scope for such productivity improvements is higher in more labour-intensive firms.

Collectively, our findings illustrate that firms differ significantly in their capacity to benefit from the potential externalities stemming from MNE activity and such differences contribute to explaining a large fraction of the heterogenous benefits.

Regional characteristics also matter, albeit to a much lesser extent than firm-level characteristics. In Mod. 6 and 7, we substitute region-fixed effects with some regional characteristics. In line with previous studies, we find a positive association with GVA per employee, and we do not find any significant effect of patents per employee. In addition, our results show that firms located in a highly specialised region benefit less from FDI, while those located in diversified regions experience greater benefits. This is consistent with the idea that more specialised regions may be more vulnerable to locking into their areas of expertise whereas the broader knowledge base of the more diversified regions allows them to better absorb spillovers from foreign MNEs (Beaudry & Schiffauerova, 2009; Wang et al., 2016).

5.3. Robustness checks

We have tested the robustness of our findings in various ways.

First, we need to recognise a limitation of our analysis that derives from the use of Fame as the main source of data. These data are reported at the level of the firm, rather than the plant. This could have implications for multiplant firms. We try and overcome this limitation in two ways. Firstly, we identify firms with no subsidiaries and replicate our analysis for this sub-sample. 52% of firms are classified as single plant firms and these firms are significantly smaller than the rest of the sample. Results of our first stage models, in Table A.3 in the online Appendix, reveal very consistent findings to those in Table 2: foreign assets have a non-significant mean effect on local firm productivity but with a large and statistically significant standard deviation. Similarly, results from Table A.6 largely confirm those in Table 3. In this sample of much smaller firms, domestic firms seem to benefit more than foreign-owned firms and the firm patent stock does not seem to affect the extent of MNE externality significantly, while patent intensity at the regional level matters more. Secondly, we adopt an even more restrictive approach following the criteria by Graham (2009) to identify single-plant companies in Fame.[11] This process returns 3303 firms, a sub-sample of firms with no subsidiaries, and these companies are, on average, smaller in terms of the number of employees, assets and turnover. Results of the first stage are reported in Table A.4 in the online Appendix, and the second stage results are reported in Table A.6 in the online Appendix. Results are consistent with the findings in Tables 2 and 3 for the first and second stages respectively.

Second, we recognise that by measuring foreign presence at the level of the administrative region (NUTS 3) our analysis may suffer from a modifiable area unit problem. To overcome this drawback, we estimate our (first and second stage) models by defining the regional variables at the travel-to-work area (TTWA).

Third, we test the robustness of our measure of TFP by value added as a measure of output in the production function, as opposed to turnover, which is used in our baseline estimations. Finally, since the entry and exit of firms increase the volatility of the measures of foreign and domestic assets, we run our models on a balanced sample, using the firms that are always in our sample for the entire period. Results from these robustness checks, again

Table 3. Heterogeneity in the foreign assets parameter. OLS regressions.

	Mod. 1	**Mod. 2**	**Mod. 3**	**Mod. 4**	**Mod. 5**	**Mod. 6**	**Mod. 7**
Firm characteristics							
Foreign-owned				0.002	−0.0043**	0.0006	−0.0060***
				(0.0018)	(0.0018)	(0.0018)	(0.0018)
Age				−0.0086***	−0.0077***	−0.0085***	−0.0077***
				(0.0012)	(0.0012)	(0.0012)	(0.0011)
Size dummy: medium				0.0231***	0.0190***	0.0232***	0.0193***
				(0.0018)	(0.0018)	(0.0018)	(0.0017)
Size dummy: large				0.0793***	0.0708***	0.0794***	0.0714***
				(0.0025)	(0.0025)	(0.0025)	(0.0025)
No. patents				0.0019***	0.0022***	0.0019***	0.0021***
				(0.0006)	(0.0005)	(0.0006)	(0.0005)
K/L ratio				−0.0039***	−0.0048***	−0.0042***	−0.0051***
				(0.0006)	(0.0006)	(0.0006)	(0.0006)
ROA				0.0227***	0.0088**	0.0239***	0.0115***
				(0.0039)	(0.0039)	(0.0039)	(0.0039)
Share foreign subsidiaries				0.0007	0.0029	0.0009	0.0031
				(0.0034)	(0.0033)	(0.0034)	(0.0033)
No. of foreign countries				0.0175***	0.0160***	0.0172***	0.0154***
				(0.0019)	(0.0019)	(0.0019)	(0.0019)
Labour productivity					0.0195***		0.0181***
					(0.0009)		(0.0009)
Regional characteristics							
Patents per employee						−0.0775	−0.0631
						(0.1826)	(0.1795)
GVA per employee						0.0034***	0.0040***
						(0.0013)	(0.0012)
Specialisation index						−0.0004***	−0.0003***
						(0.0001)	(0.0001)
Industry diversity						0.0027**	0.0031**
						(0.0013)	(0.0012)
Constant	0.0065	0.0103***	0.0099	0.01	−0.0855***	−0.0306**	−0.1291***
	(0.0149)	(0.0024)	(0.0151)	(0.0149)	(0.0153)	(0.0145)	(0.0151)

Number of observations	10828	10828	10828	10828	10828	10828	10828
R-squared	0.0308	0.0203	0.0358	0.1512	0.1839	0.1365	0.1656
R-squared adjusted	0.0178	0.0180	0.0210	0.1375	0.1706	0.1335	0.1626
Year fixed effects	yes	yes	yes	yes	yes	yes	yes
Industry FEs (NACE 2-digit)	no	yes	yes	yes	yes	yes	yes
NUTS-3 fixed effects	yes	no	yes	yes	yes	no	no

Note: The dependent variable is the predicted firm-specific coefficients associated with the variable foreign assets from Mod. 2 in Table 2. We use the post-estimation command 'predict', including reffects option within the mixed post-estimation and related 'mixed' packages in Stata 14 and 16 (StataCorp, 2013). Robust standard errors (in parenthesis below the parameter estimates) are computed based on Hornstein and Greene (2012). Asterisks denote confidence levels: $*p < 0.10$, $**p < 0.05$ and $***p < 0.01$.

presented in Tables A.3, A.4 and A.6, are in line with our baseline specifications in Tables 2 and 3.

6. CONCLUSIONS

Our paper highlights the importance of heterogeneity in the process by which local firms reap the potential benefits induced by the presence of MNEs in their region. The literature has highlighted the importance of the characteristics of locations and the nature of the recipient firms in shaping the capacity to absorb externalities from MNEs but failed to provide evidence on the relative importance of these phenomena. Using a two-stage methodology that relies on the estimation of random parameters, we have been able to fill this gap. With reference to the UK, we show that while the nature of the place is important, it explains a small fraction of the variation in the benefits from FDI. Conversely, heterogeneity across the recipient firms is vastly more important. That is to say, firms in laggard regions equipped with the right characteristics that allow them to develop an ability to recognise, assimilate and commercially apply external knowledge will gain more from inward investment than a poorly equipped firm in a leading region.

This has several policy implications. Firstly, a place-based strategy for economic recovery needs to recognise the importance of firm-level analysis because the main beneficiaries from inward investment are likely to be firms that are already successful. Thus, the impact of inward investment will be to increase rather than close the gap between the best and worst-performing firms. Inward investment policy and regional policy must not become synonymous, as this is likely to increase inequality rather than reduce it, at least at the firm level. Any strategy for attracting inward investment to laggard and peripheral regions needs to be accompanied by more general initiatives at the firm level. In the absence of these, attracting inward investment to peripheral regions may serve to increase the productivity of the region's leading firms, but it is unlikely to contribute to productivity growth more generally. In terms of the government's initiatives around levelling up, attracting foreign investors to such regions may enhance the productivity of the best-performing firms, which will, of course, increase average productivity, but it will not enhance inclusivity. Peripheral regions face dual challenges: a wider distribution of firm productivity, often characterised by a long tail of low-productivity firms, and low levels of agglomeration economies, and in the UK low levels of linkages between cities and neighbouring towns. Our findings indicate that simply attracting inward investment will not resolve these issues. Instead, cohesion policy should prioritise fostering links between high-productivity inward investors and the rest, addressing the underlying market failures.

This brings us to the second contribution, which is the significance of our findings around spatial concentration. In general, we find that firms in regions that are more specialised gain less from inward investment. This suggests that, at least for the UK, because regions with high levels of specialisation already have very thin and tight labour markets with significant skill shortages in these sectors, simply being part of one of these clusters or attracting inward investment to them is not sufficient to generate productivity growth. Indeed, inward investment in such sectors may generate significant crowding-out effects, which will hurt productivity. In a post COVID-19 world, many regions in both the developed and emerging economies are going to be seeking to attract investment in certain key sectors, often linked with high tech clusters and the transition to green tech. Returning therefore to our original question, our findings suggest that firms best placed to gain from inward investment are those that are already performing well in terms of productivity, as such inward investment spillovers in themselves cannot address long term decline, and attracting such investments cannot be seen as a panacea for regional inequality. Similarly, any policy designed to attract FDI to foster levelling up, needs to focus on the type of investment, specifically size and productivity, if such benefits are to be maintained.

These two contributions highlight the need for further work, which we suggest should focus on two specific areas. The first is one that permits a greater understanding of the ability of host locations to benefit from inward investment, and how one must contrast what this means for regions, with what this means at the level of the firm. In turn, understanding this at the level of the region when exploring the nature of spillovers, highlights the importance of regional labour markets in understanding the benefits to be gained by attracting FDI. If inward investment has the effect of increasing variations in productivity between firms, and if labour market conditions hamper productivity, then further research is needed into place-based solutions for this. For example, one might look at whether policies encourage labour mobility and skills acquisition at the level of the individual. Secondly, our findings illustrate the link between the productivity effects of inward investment, and the need to understand the types of inward investment that regions can attract, given that competition for investment is heating up post COVID-19, and there is a potential trade-off between employment and productivity. Frontier firms tend to employ fewer people but have higher rates of technological development, contributing to innovation, productivity and exporting. However, they typically do not create large numbers of jobs. The challenge therefore posed by our findings, is how regional cohesion policy can resolve this, harnessing benefits that appear to accrue to the most advanced firms, for wider sections of society. This involves integrating business support, inward investment and skills policy under regional cohesion.

AUTHOR CONTRIBUTIONS

Authors are listed in alphabetical order. All authors contributed to the article equally.

DISCLOSURE STATEMENT

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NOTES

1. Research has also looked beyond the effect of MNEs on host country firms' productivity, looking for example at wages, innovation and workers mobility (Görg & Strobl, 2005; Balsvik, 2011; Crescenzi et al., 2015; Girma et al., 2019; Andersson et al., 2022).
2. See Iršová & Havránek, 2013; Demena & van Bergeijk, 2017; Rojec & Knell, 2018 for recent surveys and meta-analyses.
3. We assume that β_i is normally distributed, namely $\beta_i \sim N(\beta, \sigma)$.
4. Each firm i operates in region r and industry s.
5. Since three sectors (NACE Rev.2 12 - Manufacture of tobacco products, 15 – Manufacture of leather and related products, 19 – Manufacture of coke and refined petroleum products) present a relatively small number of firms (i.e., 10, 44, 38, respectively), we aggregate these sectors within NACE Rev.2 11 – Manufacture of beverages, 14 – Manufacture of wearing apparel and 23 – Manufacture of other non-metallic mineral products respectively, in order to have a more precise estimation of the TFP within such industries.
6. The estimation of the production function is performed in Stata using the 'prodest' package developed by Rovigatti and Mollisi (2018).
7. We predict firm-specific coefficients using the post-estimation command 'predict', including the 'reffects' option within the mixed post-estimation and related 'mixed' (previously named 'xtmixed') packages in Stata 14 and 16 (StataCorp, 2013).
8. Table A.2 reveals that the pairwise correlations among independent variables are generally low (not higher than 0.4) and the variance inflation factors (available from the authors upon request) have values lower than 2 for all independent variables. These diagnostic tests suggest that multicollinearity is not a big issue in our second-stage estimations.
9. As a robustness check, we substitute the size dummy variables with a continuous measure of size, using the number of employees. Results for the first and second stages are consistent with the main results, and reported in the online Appendix, Tables A.5 and A.6, respectively.
10. Results available upon request.
11. In detail, we: (1) remove firms that record more than one UK trading address; (2) remove firms that have a registered office address that is different from their main trading address and (3) keep only those firms that do not have a (national or international) subsidiary company. We use the information on registered office addresses and the trading addresses of the companies in our sample, and we identify single plant companies following these criteria.

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