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Foreign direct investment, prices and efficiency: Evidence from India

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Foreign Direct Investment, Prices and Efficiency: Evidence from India

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Abstract

This paper uses a rich panel data set of Indian manufacturers to analyze the effects of foreign direct investment (FDI) on domestic firms. Detailed product-level information on prices and quantities allows us to estimate physical productivity and marginal costs. In line with the previous literature, we find little evidence for horizontal spillovers based on commonly used measures of revenue productivity. In contrast, we measure sizable efficiency gains using measures that are not affected by pricing heterogeneity. Our results indicate that domestic firms can benefit from the ability of multinational subsidiaries to produce high-quality products at relatively low costs.

JEL codes: *F61, F23, G34, L25, D22, D24*
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1 Introduction

It is well documented that multinational subsidiaries outperform purely domestic firms in terms of efficiency, value added and many other indicators.[1] Since this productivity advantage might stem from intangible assets such as management practices, innovation and knowledge (e.g., Bloom and Van Reenen, 2010; Markusen, 1997, 2004; Guadalupe et al., 2012), policy makers—especially in developing and transition economies—often hope that foreign direct investment (FDI) leads to technology spillovers to domestic firms. There is, however, little evidence that exposure to FDI is associated with positive productivity effects within the same industry (for an overview of empirical literature see Keller, 2021; Iršová and Havránek, 2013).

The lack of evidence for spillovers in the existing literature might, however, stem from the use of revenue-based measures of productivity which can be misleading in the presence of pricing heterogeneity (e.g., Syverson, 2011; Braguinsky et al., 2015; De Loecker et al., 2016). For instance, if FDI spillovers materialize as marginal cost reductions which are (partly) passed on to consumers as lower prices, revenue productivity will underestimate the efficiency gains from FDI. Further, prices and markups—and hence measured revenue productivity—might change due to competitive pressure induced by foreign investors even in the absence of changes in physical productivity. Accounting for price adjustments is therefore essential to estimate FDI spillovers.[2]

In this paper, we address this problem and use a rich data set of Indian producers to revisit the question of whether FDI leads to productivity improvements in domestic firms. A unique feature of our data set is that it contains information on prices and quantities at the firm-product level next to standard measures of firms' input expenditures. This information, together with recent methodological advances in the estimation of production functions, proposed by De Loecker et al. (2016), allows us to estimate markups, marginal costs, and physical productivity and to analyze how these variables respond to changes in FDI exposure. The use of firm-product level data also allows us to measure exposure to foreign firms in a much more precise way as previous empirical studies.[3]

The case of India is particularly interesting for several reasons. First, previous research has found that the Indian economy has been characterized by high within-industry dispersion of productivity

[1] See, for instance Greenaway and Kneller (2007), Helpman et al. (2004), Criscuolo et al. (2010) to name a few.

[2] While it is common practice to deflate revenues using broad industry-level price deflator, this is unlikely to fully address the problem in the presence of pricing heterogeneity within industries (e.g., Bloom et al., 2013; De Loecker et al., 2016). Industry-level deflators are arguably specifically problematic if they are based on broad classifications, different firm populations as the estimation sample and in the presence of multi-product firms. Smeets and Warzynski (2013) and Garcia-Marin and Voigtländer (2019) demonstrate the importance of distinguishing between revenue and physical productivity for the effects of exporting and Pierce (2011) in the context of anti-dumping. Foster et al. (2008) show that there are important differences between physical and revenue productivity when analyzing within-industry reallocation.

[3] Keller and Yeaple (2009) and Keller (2021) discuss the importance of taking multiple industry affiliations of foreign owned firms into account.

(see, for instance, Syverson, 2011) and a substantial technology gap to Western economies in most industries (e.g., Hsieh and Klenow, 2009). This implies a high potential for efficiency gains from international technology spillovers. Furthermore, various economic reforms, such as a deregulation of foreign ownership caps have induced a large inflow of FDI. Finally, in contrast to most other countries, Indian firms are required by law to report sales and quantities at the product level. This unusually rich information is essential for our empirical approach.[4]

We start by documenting performance differences between foreign- and domestically owned firms. Foreign affiliates seem to generate higher demand, charge higher markups and produce products of superior quality. They produce with similar levels of marginal costs on average, but lower marginal costs conditional on quality within product categories. This indicates that the competitive advantage of multinational subsidiaries stems from the ability to produce high-quality goods at relatively low costs.

In line with much of the previous literature, we find little evidence for productivity spillovers to domestic firms using commonly applied measures of revenue productivity at the firm-level. However, we find sizable gains based on measures that are not affected by pricing heterogeneity such as physical productivity and marginal costs. Our results indicate that although markups seem to increase—likely due to an incomplete pass-through of cost savings—part of the efficiency gains are passed on to consumers in the form of lower prices. Our results indicate that competitive pressure from foreign firms leads to a further decline in prices conditional on changes in marginal costs. These two channels can explain why revenue-based measures of productivity are biased downwards. An alternative, not mutually exclusive explanation, is that ignoring pricing heterogeneity can lead to biased elasticities in the production function which affects measured productivity and markups.[5]

Since FDI might not be allocated randomly across industries, we use instrumental variables (IV) exploiting cross-industry and time-series variation in India's FDI liberalization. Various checks indicate that these liberalization events are uncorrelated with previous performance levels and trends at the firm and industry level. Using this source of exogenous variation, we find even more substantial efficiency gains from exposure to horizontal FDI in domestic firms.[6] These results are robust towards controlling for other policy changes at the industry level such as tariffs and delicensing.

[4]Stiebale and Vencappa (2018) and Bircan (2019) provide evidence on the effects of international acquisitions exploiting product-level data for India and Turkey, respectively. However, they focus on a specific form of FDI —foreign takeovers— and the effects on acquisition targets rather than spillovers to non-merging domestic firms.

[5]Recently, Bond et al. (2020) show that without measures of quantities, it is not possible to consistently identify variation in markups and productivity across firms and time unless one imposes strong assumptions about demand or restrictions on output elasticities.

[6]Bau and Matray (2020) also study the effects of FDI liberalization in India and find a reduction in misallocation which they attribute to improved access to finance for domestic firms. In contrast, our paper analyzes within-firm changes in physical productivity due to spillovers from FDI. See Goldberg et al. (2009), Goldberg et al. (2010a), De Loecker et al. (2016) for an analysis of India's trade liberalization. Other reforms in the Indian economy are, for instance, analyzed by Aghion et al. (2008) and Martin et al. (2017).

We also provide evidence that the entry mode of FDI matters. Specifically, we find that positive spillovers seem to be more pronounced when foreign investors enter via acquisitions as opposed to greenfield investment (new firms or production units) and when there is joint domestic and foreign ownership. A likely explanation is that knowledge is more likely to spill over to domestic producers due to the involvement of a local partner and the type of technologies employed in these firms (Javorcik and Spatareanu, 2008).

Moving the analysis to the product-level, we provide evidence that technology spillovers are likely to occur across product categories. Reductions in marginal costs at a narrowly defined (12-digit) firm-product-level are driven by the exposure to FDI in related products within (3-digit) industries. The presence of foreign investors in the same product category does not seem to result in additional cost reductions conditional on industry-level exposure, but leads to a decline in prices, arguably due to increased competitive pressure. We also find that efficiency gains in domestic firms are concentrated among firms that produce products of relatively high quality to begin with. This suggests that Indian firms with sufficient absorptive capacity can learn how to produce high-quality products at relatively low costs from foreign multinationals.

Our findings are related to several strands of literature. First, there is a large literature on spillovers from foreign to domestic firms. The majority of studies finds little evidence for horizontal spillovers, i.e. productivity spillovers within the same industry. Even for developing countries, where potential efficiency gains are most substantial, the majority of existing studies has estimated insignificant or even negative effects of FDI on domestic firms (e.g., Haddad and Harrison, 1993; Aitken and Harrison, 1999; Girma et al., 2015; Lu et al., 2017). The evidence is more positive for vertical spillovers, i.e. productivity improvements in potential suppliers of multinational subsidiaries (e.g., Javorcik, 2004; Havranek and Irsova, 2011).[7]

The existing FDI literature is primarily concerned with the estimation of productivity spillovers rather than competitive effects. An exception is Aghion et al. (2009) who provide evidence that entry of foreign investors spurs innovation incentives of domestic firms in the UK. A few recent papers analyze the effects of FDI on product-level outcomes. Eck and Huber (2016) as well as well as Javorcik et al. (2018) find that horizontal FDI is correlated with higher likelihood of introducing technologically advanced products by domestic firms.

Our paper also speaks to a broader literature in international economics which has studied performance differences between domestic and foreign-owned firms and the sources of multinational's

[7]Although the direction of the bias from using revenue-based measures of productivity is more obvious for horizontal FDI, estimated spillovers across vertical chains could also be affected if changes in demand for intermediate inputs induce changes in input and output prices for domestic suppliers and buyers. Consistent with the existing literature, we provide evidence for vertical spillovers through backward linkages, i.e. from multinational subsidiaries to upstream producers, in an extension of our analysis.

productivity advantage (see Antràs and Yeaple, 2014, for an overview). Within this literature, a number of empirical studies have investigated the effect of cross-border mergers and acquisitions on various outcomes of acquisition targets (e.g. Arnold and Javorcik, 2009; Bircan, 2019; Fons-Rosen et al., 2021; Guadalupe et al., 2012; Javorcik and Poelhekke, 2017; Stiebale and Vencappa, 2018). Finally, our paper is related to a literature which investigates the effects of FDI policy on the volume of foreign investment (e.g. Harding and Javorcik, 2011) and revenue-based measures of productivity (e.g., Eppinger and Ma, 2017; Lu et al., 2017; Genthner and Kis-Katos, 2019; Bau and Matray, 2020; Conteduca and Kazakova, 2021).

We contribute to the existing literature in various aspects. First, to the best of our knowledge, this is the first paper to estimate the effects of FDI on marginal costs and markups of domestic firms. Second, we show that the absence of information on quantities and prices can lead to misleading conclusions about the existence and magnitude of FDI spillovers. We therefore argue that one reason for the lack of horizontal spillovers from FDI in the existing literature might be due to the measures of productivity employed. Third, we provide evidence on the importance of quality-based competence for the competitive advantage of multinational subsidiaries and the resulting spillovers to domestic firms. Fourth, our analysis differentiates between spillovers within and across product categories and between different modes of foreign entry which has important implications for the effectiveness of FDI policy.

The rest of the paper is organized as follows. Section 2 provides a description of our data sets and details how we estimate productivity, markups and marginal costs. Results on spillovers from FDI to domestic firms are discussed in section 3. Section 4 concludes.

2 Data and Variables

2.1 Data

Our main data source is the *Prowess* database compiled by the Centre for Monitoring of the Indian Economy (CMIE). Prowess includes financial data for both publicly listed and private firms across all sectors.[8] These firms cover more than 70% of industrial output from the organized sector and 75% of corporate taxes and 95% of excise taxes collected by the government. Prowess also records firms' product-level data on quantities and values of sales and production.[9] We extracted data spanning the period 1988 (the first year firms appear in the database) until 2017. Since our empirical framework requires comparable units for quantities and prices, we focus on the manufacturing sector.

[8]This database has been used in a number of recent papers, e.g. De Loecker et al. (2016); Goldberg et al. (2009, 2010a,b).

[9]The 1956 Companies Act requires Indian firms to disclose data at this level of detail.

Firms report names of each product alongside information on the quantity and value of production and sales. Each product in Prowess is allocated a 20-digits code from CMIE's own internal classification of 5908 sub-industries and products. Of these, 4833 products fall under the manufactured sector.[10] After cleaning the data, accounting for missing values, and aggregating products to a common 12-digit level, there are 2896 clean and unique CMIE product categories in our estimation sample. Following De Loecker et al. (2016), we choose to aggregate products to a 12-digit level because the number of observations for some narrowly defined products is very small and the degree of disaggregation varies across products and industries. The aggregated product codes were then assigned to India's National Industrial Classification (NIC) to allow matching them with FDI liberalization indicators. Prowess also contains information at the firm-level such as sales, material costs, wage bill and capital stock (measured by gross fixed assets).[11]

Prowess also contains information about the share of foreign equity for listed firms. For both listed and non-listed firms, information on whether a firm is part of a domestic (private or government) or foreign business group is available. This measure contains the percentage of foreign promoters for Indian listed companies. We complement this measure with information on firm's ownership type for non-listed firms. In our analysis we consider firms having more than 25% of foreign shares as foreign-owned firms. We consider privately Indian owned or government owned firms to have less than 25% foreign equity, and private foreign owned firms to have more than 25% foreign equity.[12]

Table 1 reports the coverage of firms, products and firms' ownership in our sample. For our empirical analysis, we use data on 9957 firms and 30013 firm-products, distributed across 11 broad two-digits manufacturing industries. About 7% of the firms in our estimation sample have at least 25% of foreign ownership, and about 60% of the firms are single product firms.[13]

[10]CMIE's classification is largely based on the Indian National Industrial Classification (NIC) and the HS schedule. Example of products across different industries include bread, shrimps, corned meat, pig iron, sponge iron, pipe fittings, rail coaches. See Goldberg et al. (2010b) for a detailed description of the product-level data in Prowess.

[11]Unfortunately, the data base does not contain direct information about the skill level of employees or the quality of capital and materials. However, as we discuss in the next section, our empirical framework will control for heterogeneity in quality using a control function approach.

[12]Eck and Huber (2016) use a similar strategy to construct a measure of foreign ownership. Our results are robust towards using alternative thresholds of foreign ownership. On average, foreign shares represent 58.5% of listed private-foreign owned firms' shares and 7.8% of listed private-Indian and government-owned firms' shares.

[13]The share of single-product firms is very similar to Bernard et al. (2010) who report a share of single-product firms of 61% in the US for the year 1997. The share of single-product firms in our sample is slightly higher than in a previous study for India by Goldberg et al. (2010b) who report a share of 53%. This difference emerges partly because coverage of relatively small firms is higher in our more recent version of Prowess and partly because we aggregate some similar product into common categories for our estimation approach. Note that in line with other studies on multi-product firms, our definition of a product refers to a category such as motorcycles or sponge iron, not a unique variety within these categories. The share of single-product firms among foreign owned firms is 5%.

2.2 Main variables

2.2.1 Estimating productivity, markups and marginal costs

To estimate productivity, markups, and marginal costs, we follow the methodology introduced by De Loecker et al. (2016), henceforth LGKP.[14] This method accounts for endogeneity of production inputs similar to standard techniques in the productivity literature (Ackerberg et al., 2015; Levinsohn and Petrin, 2003; Olley and Pakes, 1996). In addition, it relies on the availability of quantities and prices at the product level to separate physical productivity from revenue based productivity. As most (if not all) firm-product-level data sets, Prowess does not include complete information on prices of all inputs and provides data on inputs at the firm-level with no information about how inputs are allocated across products for multi-product firms.[15] The main innovations of the LGKP approach are the introduction of a control function for unobserved input prices and a method to recover the allocation of inputs across products. We briefly describe the methodology below.

Consider a production function for firm i producing a product j at time t:

$$Q_{ijt} = F_j(M_{ijt}, K_{ijt}, L_{ijt})\Omega_{it} \tag{1}$$

where Q_{ijt} denotes physical output, M_{ijt} denotes a freely adjustable input (materials in our case), K_{ijt} and L_{ijt} are capital stock and labor input respectively and Ω_{it} denotes TFP. All production inputs are defined in physical units. A firm minimizes costs for each product and takes a production function as well as input costs as given.

As shown by De Loecker and Warzynski (2012) and LGKP, this cost minimization yields an expression for the firm-product specific markup as:

$$\mu_{ijt} = \left(\frac{P_{ijt}Q_{ijt}}{W^M_{ijt}M_{ijt}}\right)\frac{\partial Q_{ijt}(.)}{\partial M_{ijt}}\frac{M_{ijt}}{Q_{ijt}} = \frac{\theta^M_{ijt}}{\alpha^M_{ijt}} \tag{2}$$

where P_{ijt} denotes the output price, W^M_{ijt} is the input price of materials, α^M_{ijt} is the ratio of expenditures on input M_{ijt} to a product's revenue and θ^M_{ijt} is the elasticity of output with respect to this input. Intuitively, the output elasticity equals the input's revenue share only in the case of perfect competition. Under imperfect competition, the output elasticity will exceed the revenue share.[16]

[14] LGKP investigate the effect of India's trade liberalization on output prices, markups and marginal costs using the same main data source, but covering an earlier time period.

[15] While Prowess contains data about the prices of material inputs, it does not contain information about the price of capital. Furthermore, for a large proportion of firms, data exists only on total wage bill but not on number of employees.

[16] This framework assumes that there are no static sources of market power in *input* markets, i.e. $\frac{\partial W^M_{ijt}}{\partial Q_{ijt}} = 0$. Further, it abstracts from misallocation which systematically distorts the use of intermediate inputs relative to other production factors.

As we describe below, θ^M_{ijt} can be estimated from a production function and α^M_{ijt} can be calculated, once the allocation of inputs across a firm's product have been estimated. Marginal costs (mc_{ijt}) can then be calculated as the ratio of observed prices to estimated markups:

$$mc_{ijt} = \frac{P_{ijt}}{\mu_{ijt}} \tag{3}$$

The basis for productivity estimation is the logarithmic version of equation (1) with an additive error term, ϵ_{ijt} which captures measurement error:

$$q_{ijt} = f_j(\boldsymbol{v}_{ijt}; \boldsymbol{\beta}) + \omega_{it} + \epsilon_{ijt} \tag{4}$$

where $\boldsymbol{v}_{ijt}$ denotes a vector of logarithmic physical inputs (capital k_{ijt}, labor l_{ijt} and materials m_{ijt}) allocated to product j and ω_{it} is the log of TFP. For our application, we mainly rely on a translog production function, hence:

$$\begin{aligned} f_j(\boldsymbol{v}_{ijt}; \boldsymbol{\beta}) = & \beta_l l_{ijt} + \beta_m m_{ijt} + \beta_k k_{ijt} + \beta_{lm} l_{ijt} m_{ijt} + \beta_{lk} l_{ijt} k_{ijt} + \beta_{mk} m_{ijt} k_{ijt} \\ & + \beta_{ll} l^2_{ijt} + \beta_{mm} m^2_{ijt} + \beta_{kk} k^2_{ijt} + \beta_{lmk} l_{ijt} m_{ijt} k_{ijt} \end{aligned} \tag{5}$$

The translog production function yields a physical output-material elasticity:

$$\theta^M_{ijt} = \beta_m + \beta_{lm} l_{ijt} + \beta_{mk} k_{ijt} + 2\beta_{mm} m_{ijt} + \beta_{lmk} l_{ijt} k_{ijt} \tag{6}$$

which varies across firms within industries and nests a Cobb-Douglas production function as a special case.[17]

Physical inputs can be expressed as $v_{ijt} = \rho_{ijt} + \tilde{v}_{it} - w_{ijt}$ where $\tilde{v}_{it}$ denotes observed input expenditures at the firm-level, ρ_{ijt} is the log of the input share allocated to product j and w_{ijt} denotes the log of an input price index (defined as deviations from industry-specific deflators). When the log of input allocations, ρ_{ijt}, is captured by a function $A(\rho_{ijt}, \tilde{\boldsymbol{v}}_{it}, \boldsymbol{\beta})$ and the log of the unobserved input price index, w_{ijt}, is captured by a function $B(w_{ijt}, \rho_{ijt}, \tilde{\boldsymbol{v}}_{it}, \boldsymbol{\beta})$, output can be rewritten as a function of firm-specific input expenditures instead of unobserved product-specific input quantities:[18]

$$q_{ijt} = f_j(\tilde{\boldsymbol{v}}_{ijt}; \boldsymbol{\beta}) + A(\rho_{ijt}, \tilde{\boldsymbol{v}}_{it}, \boldsymbol{\beta}) + B(w_{ijt}, \rho_{ijt}, \tilde{\boldsymbol{v}}_{it}, \boldsymbol{\beta}) + \omega_{it} + \epsilon_{ijt} \tag{7}$$

[17] For the Cobb-Douglas production function, $f_j(\boldsymbol{v}_{ijt}; \boldsymbol{\beta}) = \beta_l l_{ijt} + \beta_m m_{ijt} + \beta_k k_{ijt}$ and $\theta^M_{ijt} = \beta_m$.

[18] See LGKP for the exact functional form of $A(.)$ and $B(.)$ for the translog and the Cobb Douglas case.

Estimation of the parameters of the production function is based on a sample of single product firms for which $A(.)$ can be ignored. Unobserved input prices w_{it} in $B(.)$ are approximated by output prices (p_{it}), market shares (s_{it}), product dummies ($\boldsymbol{D_j}$), and export status (ex_{it}) to account for differences in product quality and local input markets. We also include a vector of variables capturing FDI ($\boldsymbol{FDI}_{it}$) which we define below, as we want to allow for the possibility that foreign ownership and the presence of foreign investors affects input prices.

Material demand is assumed to be a function of productivity, other inputs, output prices, market share, product, export and FDI, hence: $\tilde{m}_{it} = m(\omega_{it}, \tilde{k}_{it}, \tilde{l}_{it}, p_{it}, \boldsymbol{D}_j, s_{it}, ex_{it}, \boldsymbol{FDI}_{it})$. Inverting the material demand function yields an expression for productivity: $\omega_{it} = h(\tilde{\boldsymbol{v}}_{it}, \boldsymbol{c}_{it})$ where $\boldsymbol{c}_{it}$ includes all variables from the input demand function except input expenditures.

The use of single product firms induces a further complication of endogenous sample selection since single-product firms might be less productive compared to multi-product firms. Analogous to the exit correction proposed by Olley and Pakes (1996), the probability of remaining a single product firm (SP_{it}) is a function of previous year's productivity and an unobserved productivity cutoff.[19]

For the evolution of productivity, the following law of motion is assumed:

$$\omega_{it} = g(\omega_{i,t-1}, ex_{i,t-1}, \boldsymbol{FDI}_{i,t-1}, SP_{it}) + \zeta_{it} \tag{8}$$

In addition to export status and the probability of remaining a single product firm, we allow the evolution of productivity to depend on exposure to FDI. We follow LGKP and base our moment conditions of the combined error term $\zeta_{it} + \epsilon_{ijt}$ as suggested by Wooldridge (2009). We discuss how we estimate the production functions and recover unobserved input allocation across products of multi-product firms in the Appendix.

2.2.2 Indicators of product quality

We use two indicators of product quality. The first indicator directly comes from the production function estimation and is based on heterogeneity in input prices. Following LGKP, we assume that input prices are a function of product quality which in turn depends on market share and price. The idea is that high quality outputs require high quality inputs which tend to have high input prices. Our first measure of (input) quality is therefore the predicted input price index, $\hat{w}_{ijt}$, which we use in the control function.

An alternative approach to measure quality follows Amiti and Khandelwal (2013) and Khandelwal et al. (2013) and is based on the intuition that, within product categories, varieties with higher

[19] SP_{it} is estimated by a Probit regression of a dummy variable for remaining a single-product firm on $\tilde{\boldsymbol{v}}_{i,t-1}$ $\boldsymbol{c}_{i,t-1}$, investment, year and industry dummies.

quality should generate higher demand conditional on price. Under the assumption that consumers maximize a CES utility function, one can write:

$$q_{ijt} + \sigma p_{ijt} = \alpha_j + \alpha_t + \iota_{ijt} \tag{9}$$

where q_{ijt} and p_{ijt} denote logarithmic quantities and prices, α_j and α_t are product and year fixed effects and σ is the elasticity of substitution between varieties within a market.[20] Quality can be inferred from this specification as $\gamma_{ijt} = \iota_{ijt}/(\sigma - 1)$. Through the assumption of a CES utility function, this approach ignores heterogeneity of markups within product categories. Hence, this measure does not rely on our estimated production function elasticities or markups and we can check the robustness of our finding with a measure that does not rely on the correct specification of the production function. We use industry-specific levels of σ estimated for imports into India by Broda and Weinstein (2006) to avoid having to estimate demand for each product category.

3 Empirical analysis

3.1 Descriptive analysis

In this subsection, we discuss some characteristics of our firm- and product-level variables and analyze how they differ across domestic and foreign-owned firms.

Table A1 depicts median and mean elasticities of output with respect to all inputs estimated from separate production functions for each industry. We use a translog production function that allows for elasticities and return to scale parameters to vary across industries as well as firms and firm-products within industries. The estimates indicate increasing returns to scale with an average measure of 1.06 across all industries. Returns to scale for the median firm within each industry are above 1 in 9 out of 11 cases and range between 0.93 and 1.27. Table A2 shows markups of products across industries. The estimates indicate a median markup of 2.14 that ranges between 1.76 and 3.67.

Table 2 reports coefficients from OLS regression of key variables on a foreign ownership indicator and industry-year or product-year dummies. As column (1) shows, foreign owned firms generate on average almost one log point higher sales than domestic Indian firms. Columns (2) and (3) indicate that about three quarters of differences in sales are due to higher quantities produced and one quarter is due to higher prices. Columns (4) shows that foreign firms charge higher prices due to higher markups, calculated as expressed in equations (2). A plausible explanation for higher

[20] See, for instance, Khandelwal et al. (2013) for details on the derivation. A similar specification has, for instance, also been applied by Breinlich et al. (2016) recently.

quantities sold besides higher prices and markups is that foreign-owned firms produce products of higher (perceived) quality. Columns (5) and (6) confirm this hypothesis using the more formal indicators of product quality discussed in section 2.2.2. Hence, foreign firms seem to use inputs of higher quality and produce products with higher appeal to consumers.

Results in column (7) indicate that foreign-owned firms produce with slightly lower marginal costs, but the differences are statistically insignificant. However, due to relatively higher quality of their products, it is misleading to draw conclusion about foreign firms' efficiency from raw differences in marginal costs. Since high-quality products typically require more expensive inputs, the fact that foreign-owned firms do not have higher marginal costs in fact indicates superior efficiency.[21] This perception is confirmed in columns (8) and (9) where we control for quality-differences using a third-order polynomial in either the input or the output-based measure.[22] The results indicate that foreign-owned firms produce with significantly lower marginal costs *conditional on quality.* Hence, the average foreign firm produces with higher efficiency than a domestic firm that produces products of comparable quality in the same category.

Differences in physical TFP between foreign and domestic firms are statistically insignificant, but this is likely due to more elaborate production techniques that are used to produce high-quality products.[23] Finally, foreign firms seem to be more profitable on average, as indicated by higher revenue TFP, and they produce a slightly higher number of products. In the following section, we aim to analyse whether some of the superior performance of foreign-owned firms spills over to domestic firms in India.

Table A3 in the Appendix reports means and standard deviations of firm-level measures of revenue, labour, capital, materials and other variables comparing domestic and foreign owned firms at the firm-level. Foreign-owned firms generate on average higher revenues and capital stock, face higher wage bills and spend more on materials. They also produce more products but report lower export share relative to domestically owned firms.

3.2 Spillovers from FDI to domestic firms

3.2.1 Baseline specification

Our empirical strategy aims to identify the effects of FDI on domestic firms. We start by analyzing the following regression at the firm-level:

[21]The average elasticity of marginal cost with respect to quality in our sample—calculated from a simple regression of log marginal costs on log quality and product-year fixed effects— is 0.86 for input quality and 0.59 for output quality.

[22]We obtain very similar results when we control for quality without higher order terms.

[23]Consistent with Forlani et al. (2016), we find a negative correlation between physical TFP and quality. See also the discussion in Stiebale and Vencappa (2018), Appendix C.

$$\Delta y_{it} = \phi \Delta FDI_{it} + \Delta x'_{i(k)t}\gamma + d_t + [g_i] + \Delta u_{it} \tag{10}$$

Δy_{it} is the change in a firm-level outcome such as productivity of firm i at time period t. In our main specification, we use one-year differences but we also estimate the equation in two- and three-year differences. FDI_{it} measures firm-level exposure to horizontal FDI which is defined below. $x'_{i(k)t}$ is a vector of control variables where k indicates industries, d_t denotes time dummies and u_{it} is an error term. In some specifications, we add firm-fixed effects g_i to the equations in differences which control for firm-specific permanent differences in growth paths across firms. The equation is estimated for firms that are domestically owned in all time periods they enter the sample.

For product-level outcomes, we estimate a similar regression:

$$\Delta y_{ij(k)t} = \phi_1 \Delta FDI_{jt}^{product} + \phi_2 \Delta FDI_{kt}^{industry} + \Delta x'_{j(k)t}\gamma + d_t + [g_{ij}] + \Delta u_{ijt} \tag{11}$$

where j refers to a 12-digit product category within an industry k. This specification allows us to distinguish between spillovers from FDI in the same product category j and spillovers across products categories within the same industry k. We control for unobserved heterogeneity at the firm-product level, g_{ij}, using firm-product fixed effects.

Exposure to FDI at the product and industry-level is measured as the share of sales generated by foreign-owned firms[24]:

$$FDI_{jt}^{product} = \frac{\sum_{i \in j,t} s_{ijt} \times foreign_{it}}{\sum_{i \in j,t} s_{ijt}} \tag{12}$$

$$FDI_{kt}^{industry} = \frac{\sum_{i \in k,t} s_{ikt} \times foreign_{it}}{\sum_{i \in k,t} s_{ikt}} \tag{13}$$

where s_{ijt} (s_{ikt}) denotes sales at the product (industry) level and $foreign_{it}$ is a dummy variable indicating foreign ownership.[25]

To generate a firm-specific measure of FDI exposure, we aggregate FDI at the industry (or

[24] This measure of exposure to horizontal FDI is standard in the literature, see (e.g., Javorcik, 2004; Iršová and Havránek, 2013).

[25] Our results are robust to excluding the sales of firm i in the denominator of the FDI exposure measures.

product) level using lagged sales shares within firms as weights:

$$\Delta FDI_{it} = \sum_k \frac{s_{ik,t-1}}{S_{i,t-1}} \Delta FDI_{kt}^{industry} \tag{14}$$

where $S_{i,t-1}$ denotes sales at the firm level.[26] In our baseline specification, we construct firm-level exposure to FDI from 3-digit industries. However, we also experiment with 5-digit industry classifications and 12-digit product categories, replacing $FDI_{kt}^{industry}$ with $FDI_{jt}^{product}$ and $s_{ik,t-1}$ with $s_{ij,t-1}$.

We use a similar weighting scheme for control variables such as tariffs and de-licensing that are aggregated to the firm-level. For our outcome variables, we use the average of sales shares in t and $t-1$ as weights, as the composition of products can change across years.

Table 3 reports estimates of different variants of equation (10). In Panel A, one-year differences are reported. Column (1) indicates that a 1 percentage point increase in exposure to FDI induces an approximately 0.26% increase in physical productivity of domestic firms. This results indicates that domestic firms seem to be able to improve production technologies when exposed to competition by foreign multinationals.

Interestingly, when we use a measure of revenue-based TFP ($RTFP$), calculated based on the method proposed by Ackerberg et al. (2015) that is commonly used in the literature, the coefficient for FDI exposure is negative and statistically significant (see column 2). Column (3) shows estimates using changes in average prices as an outcome variable. The results show that prices of domestic firms seem to decline when the presence of foreign-owned firms increases. Columns (4) and (5) decompose changes in prices into markups and marginal costs. Interestingly, prices do not decline due to falling markups which would be expected if foreign firms would purely increase competitive pressure without generating spillovers.[27] In contrast, marginal costs decline at a magnitude that is similar to the increase in physical TFP and about half of these cost savings seem to be passed on to consumers.

The results indicate that the usual conclusion in the existing literature, that there is little evidence for horizontal spillovers in the form of efficiency gains, might at least partly be due to changes in output prices—which are hidden in commonly used measures of revenue TFP—rather than constant levels of physical TFP and production costs. To see that, note that a production function in physical units estimates: $q = v'\beta + \omega$, where v denotes a vector of inputs, while a revenue-based production function estimates $r = q + p = v'\beta + \tilde{\omega}$. For given values of β, the latter will derive an estimate of

[26] For specifications in two- and three-year differences, we construct weights based on sales shares in time period $t-2$ and $t-3$.

[27] We discuss pro-competitive effects in more detail in section 3.5.

TFP: $\tilde{\omega} = \omega + p$. Hence, lower prices imply lower values of measured revenue TFP (De Loecker et al., 2016).[28] A further source of bias when using sales data instead of quantities is that inputs v might be correlated with output prices p and hence the error term, which is not taken into account by standard estimation techniques. This might lead to biased elasticities β and hence a further bias in estimated TFP and markups.

Our specification in first differences removes permanent heterogeneity in performance levels of firms with different exposure to FDI. It is, however, important to acknowledge that these characteristics may evolve differently over time. To address this concern, we use different strategies. First, we add the lead of exposure to FDI, $\Delta FDI_{i,t+1}$ to equation (10). This allows us to test for changes in domestic firms' characteristics that took place prior to the increase in foreign presence. Results in Panel B of Table 3 show that this does not seem to be an important problem as all the coefficients for the lead indicator are rather small and statistically insignificant while the coefficients of the contemporaneous FDI variable remain stable.

Second, we add firm fixed effects to equation (10) which allows to control for permanent differences in growth paths across firms. Results in Panel C show that this even slightly increases the estimated effects on physical TFP, prices and marginal costs. In alternative specifications, which are documented in Panels D and E, we estimate the model in 2- and 3-year differences. Our conclusions regarding changes in efficiency are qualitatively the same as in the first-difference specifications. Changes in TFP and marginal costs are somewhat larger indicating that it takes some time until the spillovers are fully realized.

Third, we use instrumental variables, which exploit cross-industry and time series variation in FDI reforms. We describe this identifcation strategy in detail in the next section.

3.2.2 Using exogenous variation from India's FDI liberalization

Our baseline specification assumes that changes in exposure to foreign firms (ΔFDI_{it}) are exogenous to the growth of firm performance—conditional on firm fixed effects and other controls. Consistent with this assumption, lead variables of FDI seem to be uncorrelated with current values of firm performance. Nonetheless, although our baseline specification allows for a correlation between FDI and firm- and industry-specific growth paths, a potential concern is that foreign investors select into industries based on changes in expected future growth leading to a spurious correlation between FDI

[28] If prices were constant across firms within an industry, output prices could be controlled for by commonly used industry deflators. However, this is not the case if there is pricing heterogeneity across firms within industry—which is common in our sample. Further, even if there was no pricing heterogeneity within industries, aggregate deflators that will assign one industry code per firm will still not by sufficient since many firms produce outputs in various industries. Note that the expression abstracts from input price heterogeneity which is taken into account in our empirical framework.

exposure and efficiency. To address this potential concern, we exploit cross-industry and time-series variation in India's FDI liberalization within an instrumental variable approach.

Prior to 1991, foreign investment in India was only allowed in few industries through governmental approval and was restricted to 40% of equity. Upon the adoption of the IMF structural adjustment program in august 1991[29], the cap on foreign equity increased to 51% and became automatically approved. Since then, the cap on foreign equity as well as the number of liberalized manufacturing industries started to increase gradually.

We followed Bau and Matray (2020) and collected yearly changes in FDI liberalization reforms using official press notes published by the Indian Ministry of Commerce and Industry.[30] We mapped the list of collected industries to five-digit industries in Prowess which are based on the national industry classification (NIC). We found that a total of 37 five-digit manufacturing industries were liberalized to allow up to 100% foreign equity by 2006. We choose to focus our instrumental variable analysis on the list of industries that were liberalized after 2000, to avoid capturing the effect of other major reforms during the nineties such as delicensing and trade liberalization.[31] Therefore, our instrument captures the change in FDI policy that happened after 2000 at the five-digit industry level (which affected 6% of industries in our sample). Nonetheless, we control for measures of tariffs and delicensing in some of our specifications as a robustness check. A list of liberalized industries can be found in Table A4 in the Appendix.

A potential concern is that FDI liberalization did not occur randomly but was targeted towards industries based on their performance. For instance, policy makers might believe that industries with specific characteristics might cope with foreign competition in a better way or have the absorptive capacity to benefit from spillovers. To investigate whether this is likely to be the case, we checked the correlation between the incidence of FDI liberalization and past performance at the 5-digit industry level.[32] Specifically, we regressed a dummy variable for FDI liberalization in a current year on lagged levels and growth rates of domestic market size (captured by the log of total sales), and average values of TFP, capital intensity, markups, prices, and marginal costs. Table 4 shows results from linear probability models which indicate that neither lagged levels, 1-year or 3-year growth rates of any of these variables are statistically significantly correlated with FDI liberalization. As depicted in Table A5, A6 and A7 in the Appendix, we reach the same conclusion when we estimate a Probit

[29]After a balance of payment crisis in India in 1990, IMF support was granted conditional on reforms including foreign equity liberalization, tariff reductions and delicensing during the 1990s. See Topalova and Khandelwal (2011) for a detailed discussion.

[30]These are available at `https://dipp.gov.in/policies-rules-and-acts/press-notes-fdi-circular`, accessed March 8, 2020.

[31]See, for instance, Aghion et al. (2008) and De Loecker et al. (2016) for analyses of delicensing and trade reforms in India.

[32]Our approach is similar to Topalova and Khandelwal (2011) who analyze the potential endogeneity of India's trade liberalization to industry characteristics and firm performance.

model instead of a linear probability model and when we run separate regressions for the two main liberalization episodes 2001 and 2006.

As the results are consistent with FDI liberalization events being exogenous to the performance of domestic firms, we proceed with assessing their impact on firm- and industry-level exposure to foreign investors using the following equation at the firm-level:

$$\Delta FDI_{it} = \alpha_i + \delta POSTlib_{it} + \tau_t + e_{it}$$

The firm-specific variable $POSTlib_{it} = \sum_k s_{ik} POSTlib_{kt}$ captures exposure to FDI reforms, where s_{ik} denotes the share of sales that firm i generates from 5-digit industry k and $POSTlib_{kt}$ denotes the post-liberalization period and equals one for all periods following FDI liberalization in a given five-digit industry. We estimate these equations using firm fixed effects to account for unobserved heterogeneity. Columns (1)-(3) of Table 5 show variants of this specification using different lags of the post-liberalization indicator. It seems that foreign investors respond to the liberalization with a lag as the association between post-liberalization periods and foreign investor presence is increasing over time. This is in line with Harding and Javorcik (2011) who find that the effects of investment promotion on FDI inflows is strongest after 2-3 years.[33] A potential concern is that FDI flows react in advance to expected liberalization events in the future. However, column (4) indicates that leads of FDI liberalization periods do not seem to be affecting current exposure to FDI indicating the limited role of anticipation effects. Column (5) interacts the post-liberalization dummy with indicators for the years 2004-2011. Having shown the relevance of investment liberalization for FDI exposure, we use post-liberalization periods interacted with time dummies as an IV for our performance regressions.

A potential threat to our identification strategy is that other reforms might be confounding with FDI liberalization episodes. Although the most significant changes induced by these reforms took place before the FDI liberalization period on which we focus, we asses the robustness of our results towards controlling for trade liberalization and de-licensing. Specifically, we use industry-level tariffs and dummy variables for de-licensing which we weight by firms' sales share in the same way as our FDI liberalization indicators.[34]

Table 6 shows second stage results of our instrumental variable strategy. The first stage F-

[33]Note that as our variable of interest is measured as the market share of foreign investors, there might be an additional time lag between foreign entry and FDI exposure.

[34]We collected information on delicensing from Aghion et al. (2008) and from official press notes published by the Indian Ministry of Commerce and Industry. Tariff data were sourced from the World Integrated Trade Services (WITS).

test shows that our excluded instruments are highly statistically significant and above conventional critical values of weak identification tests. The results confirm the conclusions of our OLS regressions. Exposure to FDI — induced by FDI liberalization — generates higher physical TFP, lower prices and lower marginal costs for domestic firms. Again, using a revenue-based measure of TFP does not uncover positive spillovers. In contrast to the OLS regressions, the positive coefficient on markups is now statistically significant, indicating incomplete pass-through of cost savings to consumers. The magnitudes of the estimated effects is larger than in the OLS estimates. For instance, a one percentage point increase in FDI induced by liberalization generates a marginal cost reductions of approximately 1.45%. A potential explanation for the larger magnitudes compared to the baseline OLS regressions is that the IV estimates reflect local average treatment effects, i.e. firms in liberalized industries might benefit more from spillovers than the average firm across industries. Alternative partial explanations are a bias towards zero in OLS estimates due to a self-selection of foreign investors into industries with lower future productivity growth or measurement error in our FDI exposure variable.

3.2.3 Heterogeneous entry modes

In this subsection, we analyze heterogeneity with respect to the mode of foreign entry. Our first dimension of entry heterogeneity distinguishes between greenfield investments and cross-border mergers and acquisitions (M&As). This dimension is important from an economic policy point of view, as policy makers often provide incentives for greenfield FDI while restrictions towards international M&As are quite frequent (e.g., UNCTAD, 2000). However, as argued for instance by Crespo and Fontoura (2007), international M&As might have larger potential for spillovers. First, acquired firms' production is likely to be more related to technologies typically employed by firms in the host country. Second, acquired firms are likely to be more integrated into the local economy compared to newly founded subsidiaries of foreign multinationals.[35] For the same reason, one might expect higher spillovers from firms with partial relative to full foreign ownership. Further, as argued by Javorcik and Spatareanu (2008), foreign investors might transfer less sophisticated technologies to partially owned foreign affiliates which can be easier absorbed by domestic firm.

Panel A of Table 7 shows results of regressions in which we differentiate between greenfield and acquisition FDI. Productivity gains and cost reductions seem to be mainly driven by cross-border M&As, while spillovers from greenfield investments are small and insignificant. Interestingly, prices and markups in domestic firms seem to be declining when greenfield FDI increases. This seems plausible as the entry of new firms arguably leads to increased competitive pressure on domestic firms.

[35] Spillovers might, however, also differ across entry modes because different types of foreign investors self-select into acquisitions and greenfield investments (e.g., Nocke and Yeaple, 2007, 2008).

In contrast, the results suggest that cross-border M&As are associated with increasing markups but declining prices in domestic firms. In Panel B, we differentiate between spillovers from FDI projects with full (100%) and partial ownership (at least 25% but less than 100%) foreign ownership. The results suggest that overall spillovers from FDI are, as expected, indeed mainly driven by firms with partial foreign ownership.

3.3 Competitive effects of FDI: markups and business stealing

Our results so far have indicated that the presence of foreign investors can generate spillovers to domestic firms, but have mixed effects on domestic firms' markups. In this subsection, we discuss potential pro-competitive effects of FDI. Note that non-negative (average) effects of FDI on markups do not allow us to draw conclusions about competitive effects. The reason is that FDI generates spillovers in the form of lower marginal costs which will affect markups in the presence of incomplete pass-through. Hence, we need to condition on marginal cost changes to identify pro-competitive effects.[36] We rerun our baseline markup regression controlling for a third order polynomial of changes in marginal costs, to allow for a flexible relationship between costs and markups. Results depicted in column (1) of Table 8 indicate that conditional on changes in marginal costs, markups indeed fall when exposure to FDI increases. A 10 percentage point increase in FDI exposure leads to a 1.4% reduction in markups—conditional on marginal cost changes and their effects on markups through incomplete pass-through.

This pro-competitive effect raises the question to which extent domestic firms are crowded out by foreign investors. Columns (2) and (3) in Table 8 show results using firm-level sales and quantities as outcome variables.[37] Results indicate that foreign presence induces a decline in sales of domestic firms. More than two thirds of this decline in sales is due to lower prices, while the effect on quantities is negative but not statistically significant.[38]

In models with imperfect competition, lower marginal costs are associated with lower prices and higher demand. In contrast, competitive pressure, for instance induced by entry, would lead to lower prices and lower demand for incumbent firms. Hence, if foreign firms would purely generate positive spillovers without taking demand away from Indian firms, we would expect quantities of domestic firms to increase when marginal costs and prices fall. The combination of lower marginal costs, lower prices and declining (or non-increasing) quantities therefore suggests that FDI leads to both

[36] See LGKP for a related discussion in the context of India's trade liberalization. The average pass-through rate in our sample, estimated from a regression of changes in log prices on changes in log marginal costs is about 0.29, slightly below the one estimated by LGKP.

[37] To obtain changes in weighted firm-level quantities, we deflate observed firm-level sales by prices.

[38] Note that changes in the log of sales are exactly due to changes in log quantities plus changes in log prices. Results are qualitatively similar and more pronounced, although less precisely estimated, when we use liberalization episodes as instruments, as documented in Table A8 in the Appendix.

technology spillovers and competitive pressure.

3.4 Product-level analysis

In this section, we move the analysis to the product level to obtain a better understanding about where efficiency gains and price reductions are realized.

Table 9 shows estimates of equation (11) in which we relate product-level prices, markups and marginal costs to industry (3-digit) and product-level (12-digit) exposure to FDI. Note that the industry measure of FDI includes FDI in the same product category. Hence, the coefficient for industry-level FDI has to be interpreted conditional on foreign exposure at the product-level, while the coefficient for product level FDI measures differences between spillovers within and across product categories. In Panel A, we report results using OLS specifications in first differences with firm-product and year fixed effects. The results in column (1) indicate that exposure to FDI leads to a decline in prices and this effect is stronger within the same product category. A one percentage point increase in the market share of foreign investors in other product categories in the same industry results in an approximately 0.16% decrease in prices of domestic firms and the decrease is about 0.09% larger for FDI in the same product category.[39] In columns (2) and (3), we decompose changes in prices into markups and marginal costs. The results indicate that the reasons for price declines differ between industry- and product-level exposure to FDI. The more negative price effects for product-level FDI seem to be entirely due to declining markups while there is no evidence for additional changes in marginal costs. These results are consistent with a competition effect rather than technology spillovers from FDI. When competitive pressure from foreign firms in the same product category increases, domestic firms are induced to reduce their margins.

In contrast, price declines due to foreign exposure in other product categories are entirely due to reductions in marginal costs which are partly passed on to consumers. These results are consistent with technology spillovers rather than a competition effect. This seems plausible as the degree of competition across product categories is arguably limited. As an example consider the industry "manufacture of food products" (NIC code 107) which includes products such as bread, cocoa beans, pizzas and sugar. Another example is the industry "Manufacture of rubber products" which includes products such as cycle tyres, moped tyres, foam & rubber mattresses and rubber foam. It is clear that from a consumer's perspective, different products within an industry are unlikely to be substitutes. However, similar production processes are often used across products within industries which makes technology spillovers plausible.

Some readers might find it surprising that spillovers are not higher within than across product

[39] These numbers are calculated as $\exp(-0.093) - 1$ and $\exp(-0.173) - 1$.

categories. However, this is in line with the existing literature on spillovers which provides more robust evidence for cross-industry (Jacobian) compared to within-industry (Marshallian) spillovers (see the overview in Beaudry and Schiffauerova, 2009). A possible explanation for the lack of additional spillovers within product categories is that competition negatively impacts domestic firms due to business stealing which forces them to move up their marginal cost function (Aitken and Harrison, 1999) or reduces incentives for technology adoption if domestic firms are too far away from the technological frontier (Aghion et al., 2009).

Panel B of Table 9 shows corresponding instrumental variable results. We use two separate instruments for the product-level regressions: $POSTlib_{kt}$, a dummy variable indicating post-liberalization periods in liberalized industries and $POSTlib_{kt} \times \frac{s_{j,t-1}}{s_{k,t-1}}$, i.e. post-liberalization dummies weighted by lagged sales shares of products within industries (to predict FDI exposure at the product-level). The second instrument relies on the assumption that firms do not shift production across products within industries in anticipation of FDI liberalization.[40] Although the estimates are quite noisy, the results confirm that efficiency gains in the form of lower marginal costs are realized from spillovers at the industry-level while there is no evidence for additional gains from exposure to FDI in the same product category. The results of the over-identification tests show that for conventional levels of significance, we cannot reject exogeneity of each instruments once we accept exogeneity of the other. The corresponding first stage results, depicted in Table A9 in the Appendix, show that the instruments are jointly significant and above common thresholds of conventional critical values of weak identification tests.

3.5 Heterogeneity in spillovers: firm- and product-level characteristics

The results of the previous subsections show that domestic firms can increase their efficiency when they are exposed to foreign investors. In this subsection, we try to understand where these efficiency gains are realized. For this purpose, we estimate heterogeneous effects which account for initial characteristics of domestic firms and the products they produce.

First, we split firm-level regressions into quartiles according to initial values of size and TFP. Table 10 shows the results of this sample split. The table indicates that efficiency gains from FDI are concentrated among rather large domestic firms, those with intermediate values of physical TFP and those with medium to high revenue TFP. This result is consistent with the perception that the absorptive capacity of domestic firms matters for the degree of FDI spillovers (e.g., Crespo and Fontoura, 2007). While it might seem surprising that it is not necessarily the most productive domestic firms that benefit from the presence of foreign investors, it should be kept in mind that

[40]We found very similar results when we measure sales shares at the beginning of our sample period.

foreign investors' competitive advantage does not seem to lie in low cost production per se, but the ability to produce high-quality goods with relatively high efficiency (see Table 2).

In Table 11, we look at heterogeneous effects on marginal costs at the product level and split the sample into quartiles according to initial values of marginal costs and quality at the firm-product level. Interestingly, the results indicate that efficiency gains are mostly realized in high-cost and high-quality products. Overall, gains from FDI seem to be concentrated among those domestic firms that are initially relatively similar to foreign investors: large firms producing products of high quality which are, however, not physically more productive than the average firm. Given the characteristics of foreign-owned firms, it seems plausible that technology spillovers are concentrated among domestic firms that specialize in high-quality production rather than in low-cost firms.

3.6 Robustness Checks

In this subsection, we discuss the results of various additional robustness checks which include the measurement of FDI exposure, additional control variables, excluding firms with government ownership and possible non-linear effects. The results are documented in the Appendix.

We start by discussing alternative measures of firm-level exposure to FDI. In the baseline specification, we calculate the market share of foreign investors at the 3-digit industry level which we then aggregate to the firm-level using initial sales shares within firms as weights. As it is a priori not obvious which level of aggregation is most appropriate, we calculated alternative firm-level FDI exposure measures based on FDI at the 5-digit (industry) and 12-digit (product) level. The results of OLS and IV results, which are depicted in Tables A10 to A13 in the Appendix, show that our conclusions are robust towards alternative ways of aggregating FDI exposure to the firm-level.

Our instrumental variable exploits industry-level variation in FDI regulations. It is therefore important, that this variable does not pick up the effect of other policy reforms that are not directly related to foreign investment. For this purpose, we added control variables for delicensing and tariffs which we obtained from Aghion et al. (2008) and from World Integrated Trade Services (WITS), respectively. Delicensing is measured by the fraction of products within an industry where delicensing took place. Tariffs are measured as the average of most-favoured nation tariffs across products, defined according to the HS classification, within industries. We aggregate these measures to the firm-level using sales shares as weights, i.e. we use the same level of aggregation as for our measure of FDI exposure.[41] As Table A14 shows, our IV results do not change notably when these control variables are added.

[41] Note that our classification of products in Prowess is not identical to the HS classification which is why we have to aggregate tariffs to the industry-level first.

Our estimation procedure for production functions, and especially the measurement of markups and marginal costs, assumes that firms minimize costs. While this assumption is plausible for the vast majority of firms, it might be violated for firms with government ownership which can follow different objectives. For this purpose, we reran our IV regressions excluding state-owned firms. Results in Table A15 shows that this does not affect our main conclusions.

While the focus of our paper lies on horizontal FDI, previous research has found evidence for significant vertical spillovers. We follow Javorcik (2004) and add measures of backward and forward FDI which capture exposure to foreign investment in upstream and downstream industries, weighted by input-output coefficients:

$$FDI_{kt}^{back} = \sum_{l \neq k} \alpha_{kl} FDI_{kt} \tag{15}$$

where α_{kl} is the proportion of sector k output supplied to sector l

$$FDI_{kt}^{forw} = \sum_{m \neq k} \sigma_{km} \frac{\sum_{i \in m} foreign_{it} \cdot (S_{it} - EX_{it})}{\sum_{i \in m} (S_{it} - M_{it})} \tag{16}$$

where σ_{km} is the share of inputs purchased by industry k from industry m in total inputs sourced by sector j and EX denotes exports. Again, we aggregate vertical FDI exposure to the firm-level using sales shares as weights.

We use input-output coefficients from the World Input-Output Database (WIOD, 2016 release). We experimented with time-constant IO-weights calculated from the year 2003 to reduce endogeneity problems and time-varying IO weights which are more prone to endogeneity concerns but measure industry-linkages over a long sample period more accurately.[42] Results in Table A16 indicate positive FDI spillovers through backward linkages on TFP. This is consistent with conclusions from the existing literature. We also find a negative effect on prices and marginal costs of domestic firms. Most importantly, none of the measures of vertical FDI affects our conclusions regarding the effect of horizontal foreign investment.[43]

As a further check, we also constructed a measure of input similarity following Boehm et al. (2022). This variable is constructed as the inner product of industries' input expenditure shares. It varies between zero (when two industries have no inputs in common) and one (when all expenditure

[42] Due to a lack of IO tables for earlier years, we restrict the sample for this robustness check to years after 2000.

[43] Our conclusion regarding the effect of horizontal foreign direct investment don't change when we calculate exposure to vertical FDI based on OECD IO tables or construct IO tables from Prowess by using information on raw material inputs for single product firms which can be assigned to industries in a similar way as production outputs.

shares of the two industries are identical). We then calculate an input similarity weighted FDI exposure measure as:

$$ISFDI_{kt} = \sum_{o \neq k} \kappa_{ko} FDI_{ot} \tag{17}$$

where κ_{ko} measures input similarity between industries k and o.

Results depicted in Table A17 indicate that this additional control variable does not affect our conclusions either.

Furthermore, we ask whether the effect of FDI on the productivity of domestic firms is monotonous or becomes negative if foreign investors' market share becomes too high. For this purpose, we add a squared term of changes in FDI exposure to our baseline model. Results in Table A18 show that for our main measures of efficiency, physical TFP and marginal costs, there is little evidence for non-linear effects.

4 Conclusion

A large literature documents superior performance of multinational subsidiaries relative to domestic firms. The entry of multinationals through foreign direct investment therefore has the potential to generate positive productivity spillovers. Empirical studies have, however, mostly measured insignificant or even negative spillover effects from exposure to FDI in the same industry. We argue that a potential explanation for this results is the use of revenue-based measures of productivity which are affected by prices. If domestic prices decline when exposure to foreign multinationals increases, revenue productivity underestimates efficiency gains from FDI.

In this paper, we exploit a data set which includes prices and quantities at the firm-product level for the Indian manufacturing sector. This data, together with recent advances in the estimation of production functions, allows us to estimate the effects of FDI on marginal costs and physical productivity of domestic firms. In line with most of the previous literature, we find little evidence for technology spillovers based on commonly used measures of revenue productivity. In contrast, we estimate sizeable gains using measures that are not affected by pricing heterogeneity. Our baseline regressions indicate that a 1 percentage point increase in FDI exposure, measured as the share of output produced in foreign-owned firms, results in a 0.26% increase in physical TFP and an approximately 0.3% decrease in marginal costs of domestic firms. Using exogenous variation from India's FDI liberalization, we estimate even larger gains for increased FDI exposure induced by liberalization events. Since these efficiency are partly passed on to consumers in the form of lower prices, they might be hidden in measures of revenue TFP that have been commonly used in the FDI literature.

Our product-level results indicate that there are substantial spillovers across products within industries which lead to lower marginal costs in domestic firms. Exposure to FDI in the same narrowly defined product category leads to a decline in markups and prices but little additional changes in marginal costs. Positive spillover effects seem to be concentrated among relatively large firms with intermediate productivity levels and producers of high-quality products. Interestingly, these seem to be those domestic firms that are relatively similar to the average foreign firm to begin with. We also provide evidence that positive spillovers are more likely to occur from FDI projects with partial ownership and from acquisition FDI rather than greenfield investments.

From an economic policy point of view, our results indicate that FDI reforms can increase the efficiency of domestic firms in liberalized industries. Since spillovers seem to materialize across products within industries, attracting FDI might be most beneficial in product categories that share technological similarities with related products produced by domestic firms even if they do not compete in the same product market. Since spillovers seem to be concentrated among high-quality producers, FDI liberalization might yield higher gains once industries in developing countries have reached a certain level of maturity. Finally, although policy makers often favor greenfield over acquisitions FDI, our results suggest that easing restrictions towards international M&A may results in higher technology spillovers. For future research, it would be interesting to analyze if our results hold in different countries with different levels of development. It would also be interesting to analyze how domestic firms change their product characteristics in the long run when they are exposed to foreign competition.

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Tables

Table 1: Firms, products and ownership across industries

NIC codes	Sector	All firms	Single product	No. of products	Domestic	Foreign
10, 11, 12	Food, beverages and tobacco	1505	766	254	1418	87
13, 14, 15	Textiles, wearing apparel and leather	1478	851	208	1444	34
16, 17, 18	Wood, paper products and printing	430	305	80	413	17
19, 20, 21	Coke, chemicals and pharmaceuticals	2106	1118	919	1917	189
22	Rubber and plastics	610	408	127	578	32
23	Non-metallic minerals product	410	319	110	382	28
24, 25	Basic metal and fabricated metal	1496	895	224	1437	59
26	Computers & electronics	458	301	338	404	54
27	Electrical	416	276	201	377	39
28	Machinery & equipment	594	360	283	503	91
29, 30	Motor vehicles and transport equipment	454	356	152	392	62
10-30	All manufacturing	9957	5955	2896	9265	692

Table 2: Foreign ownership premia

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(sales) product	ln(quantity) product	ln(price) product	ln(markup) product	ln(quality) input product	ln(quality) output product
Foreign	0.998***	0.750***	0.248***	0.271***	0.237***	0.719***
	(0.086)	(0.113)	(0.078)	(0.065)	(0.078)	(0.095)
N	165940	165940	165940	165940	165940	165940
Product-year FE	Yes	Yes	Yes	Yes	Yes	Yes
	(7)	(8)	(9)	(10)	(11)	(12)
	ln(marginal cost) unadjusted product	ln(marginal cost) quality-adj. product		ln(QTFP) LGKP firm	ln(RTFP) ACF firm	ln(products) count firm
Foreign	-0.023	-0.236***	-0.463***	-0.081	0.134***	0.096***
	(0.103)	(0.069)	(0.081)	(0.114)	(0.020)	(0.031)
N	162594	162594	162594	46469	46469	46469
Product-year FE	Yes	Yes	Yes	No	No	No
Industry-year FE	No	No	No	Yes	Yes	Yes
Input-quality control	No	Yes	No	No	No	No
Output-quality control	No	No	Yes	No	No	No

Notes. The table reports coefficients from OLS regressions. Foreign is a dummy variable indicating foreign ownership of at least 25%. Dependent variables in columns 1-9 denote products' sales, quantity, price, markup, quality and marginal cost. Markup and marginal cost are calculated as expressed in equations 2 and 3. Indicators for product quality are calculated as explained in section 2.2.2. In columns 8-9, we control for a third-order polynomial in input and output quality control. ln(QTFP) denotes the logarithm of physical total factor productivity at the firm-level. ln(RTFP) denotes the logarithm of revenue-based total factor productivity at the firm-level estimated using the method proposed by Ackerberg et al. (2015). ln(products) denotes firm's number of products. Standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table 3: Horizontal FDI and firm-level outcomes

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
Panel A: 1-year differences					
ΔFDI	0.259**	-0.118**	-0.152**	0.149	-0.301***
	(0.121)	(0.049)	(0.064)	(0.095)	(0.112)
N	33168	33168	33168	33168	33168
Year FE	Yes	Yes	Yes	Yes	Yes
Panel B: Adding a lead indicator					
ΔFDI	0.256**	-0.114**	-0.151**	0.148	-0.299***
	(0.119)	(0.049)	(0.063)	(0.094)	(0.111)
ΔFDI_{t+1}	-0.023	0.032	0.008	-0.006	0.014
	(0.110)	(0.037)	(0.043)	(0.070)	(0.081)
N	33168	33168	33168	33168	33168
Year FE	Yes	Yes	Yes	Yes	Yes
Panel C: Firm fixed effects					
ΔFDI	0.377***	-0.107**	-0.200***	0.136	-0.336***
	(0.132)	(0.052)	(0.064)	(0.100)	(0.118)
N	33168	33168	33168	33168	33168
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Panel D: 2-years differences					
ΔFDI	0.447***	-0.028	-0.226***	0.284**	-0.510***
	(0.160)	(0.060)	(0.077)	(0.126)	(0.151)
N	25908	25295	25908	25908	25908
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Panel E: 3-years differences					
ΔFDI	0.455**	-0.054	-0.105	0.438***	-0.544***
	(0.200)	(0.079)	(0.094)	(0.158)	(0.193)
N	20432	19925	20432	20432	20432
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from OLS estimations. ΔFDI denotes horizontal foreign direct investment at the 3-digit industry-level weighted using initial sales shares of products within firms. $\Delta ln(QTFP)$ denotes the logarithm of physical total factor productivity at the firm-level. $\Delta ln(RTFP)$ denotes the logarithm of revenue-based total factor productivity at the firm-level measured using Ackerberg et al. (2015) methodology. $\Delta ln(price)$ is the logarithm of firm-level products' price weighted using initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted using initial sales shares of products within firms. $\Delta ln(marginalcost)$ is the logarithm of firm-level products' marginal cost weighted using initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table 4: Exogeneity of India's FDI liberalization reforms

Panel A:	dependent variable: *lib*								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$ln(marketsize)_{t-1}$	0.001								
	(0.003)								
$\Delta ln(marketsize)_{t-1}$		-0.004							
		(0.006)							
$\Delta ln(marketsize)_{t-3}$			-0.005						
			(0.007)						
$capitalintensity_{t-1}$				0.000					
				(0.000)					
$\Delta capitalintensity_{t-1}$					0.000				
					(0.000)				
$\Delta capitalintensity_{t-3}$						0.000			
						(0.000)			
$ln(QTFP)_{t-1}$							-0.004		
							(0.004)		
$\Delta ln(QTFP)_{t-1}$								-0.004	
								(0.004)	
$\Delta ln(QTFP)_{t-3}$									-0.001
									(0.003)
N	622	610	601	622	610	601	622	610	601

Panel B:	dependent variable: *lib*								
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
$ln(markup)_{t-1}$	0.001								
	(0.006)								
$\Delta ln(markup)_{t-1}$		-0.001							
		(0.005)							
$\Delta ln(markup)_{t-3}$			-0.002						
			(0.005)						
$ln(price)_{t-1}$				0.002					
				(0.002)					
$\Delta ln(price)_{t-1}$					0.002				
					(0.003)				
$\Delta ln(price)_{t-3}$						0.003			
						(0.002)			
$ln(marginalcost)_{t-1}$							0.002		
							(0.003)		
$\Delta ln(marginalcost)_{t-1}$								0.001	
								(0.003)	
$\Delta ln(marginalcost)_{t-3}$									0.004
									(0.003)
N	616	606	596	622	610	601	616	606	596

Notes. The table reports coefficients from linear probability models. *lib* denotes FDI liberalization reforms at the 5-digit industry-level. *marketsize* denotes domestic market size measured as the logarithm of total sales aggregated at the 5-digit industry-level. *capitalintensity* denotes capital intensity measured as the ratio between firms' capital value (fixed assets) and wages aggregated at the 5-digit industry-level. $ln(QTFP)$ denotes the logarithm of industry-level firms' physical total factor productivity weighted using firm's share of sales within industries. $ln(price)$ $ln(markup)$ and $ln(marginalcost)$ denote the logarithm of industry-level product price, markups and marginal cost weighted using firm's share of sales within industries. Standard errors are clustered at the five-digit industry level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table 5: FDI liberalization reforms and firm-level exposure to FDI

	(1)	(2)	(3)	(4)	(5)
			ΔFDI		
$POSTlib_t$	0.015***			-0.003	
	(0.001)			(0.003)	
$POSTlib_{t-1}$		0.020***		-0.006*	
		(0.001)		(0.003)	
$POSTlib_{t-2}$			0.026***	0.034***	
			(0.002)	(0.003)	
$POSTlib_{t+1}$				-0.001	
				(0.003)	
$D(2004) \times POSTlib_{t-2}$					0.016***
					(0.002)
$D(2005) \times POSTlib_{t-2}$					0.029***
					(0.002)
$D(2006) \times POSTlib_{t-2}$					-0.001
					(0.001)
$D(2007) \times POSTlib_{t-2}$					0.001
					(0.001)
$D(2008) \times POSTlib_{t-2}$					0.086***
					(0.003)
$D(2009) \times POSTlib_{t-2}$					0.019***
					(0.002)
$D(2010) \times POSTlib_{t-2}$					-0.003**
					(0.002)
$D(2011) \times POSTlib_{t-2}$					0.076***
					(0.005)
N	33168	33168	33168	33168	33168
Firm FE	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes

Notes. The table reports coefficients from OLS estimations. ΔFDI denotes horizontal foreign direct investment at the industry-level weighted by initial sales shares of products within firms. *POSTlib* denotes post-liberalization periods, which equals one for all periods following FDI liberalization in a given five-digit industry, and is also aggregated to the firm-level using sales shares. Standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table 6: Horizontal FDI and firm-level outcomes: 2sls estimation

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
ΔFDI	1.180**	-0.327	-0.563*	0.903**	-1.466***
	(0.500)	(0.228)	(0.337)	(0.402)	(0.503)
N	33168	33168	33168	33168	33168
First stage F-test			216.408		
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from instrumental variable estimations with firm and year fixed effects. ΔFDI denotes horizontal foreign direct investment at the 3-digit industry-level weighted by initial sales shares of products within firms. $\Delta ln(QTFP)$ denotes the logarithm of physical total factor productivity at the firm-level. $\Delta ln(RTFP)$ denotes the logarithm of revenue-based total factor productivity at the firm-level estimated by the Ackerberg et al. (2015) methodology. $\Delta ln(price)$ is the logarithm of firm-level products' price weighted using initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted using initial sales shares of products within firms. $\Delta ln(marginalcost)$ is the logarithm of firm-level products' marginal cost weighted using initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table 7: Spillovers from different entry modes

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
Panel A: Greenfield vs. M&A					
ΔFDI^{MA}	0.517***	-0.036	-0.197***	0.320***	-0.517***
	(0.161)	(0.055)	(0.074)	(0.109)	(0.130)
ΔFDI^{GF}	0.044	-0.275***	-0.207**	-0.305*	0.098
	(0.228)	(0.083)	(0.088)	(0.174)	(0.199)
Panel B: Full vs. partial foreign ownership					
ΔFDI^{full}	0.236*	-0.141**	-0.199***	-0.014	-0.185
	(0.138)	(0.059)	(0.068)	(0.116)	(0.134)
ΔFDI^{part}	0.507***	-0.076	-0.201***	0.272***	-0.473***
	(0.148)	(0.056)	(0.069)	(0.105)	(0.124)
N	33168	33168	33168	33168	33168
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from OLS estimations. ΔFDI^{MA}, ΔFDI^{GF}, ΔFDI^{full} and ΔFDI^{part} denote horizontal foreign direct investment from M&A, greenfield investments, full and partial foreign ownership, respectively. These measures are calculated at the 3-digit level and weighted using initial sales shares of products within firms. $\Delta ln(QTFP)$ denotes the logarithm of physical total factor productivity at the firm-level. $\Delta ln(RTFP)$ denotes the logarithm of revenue-based total factor productivity at the firm-level measured using Ackerberg et al. (2015) methodology. $\Delta ln(price)$ is the logarithm of firm-level products' price weighted using initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted using initial sales shares of products within firms. $\Delta ln(marginalcost)$ is the logarithm of firm-level products' marginal cost weighted using initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table 8: Competitive effects of FDI

	(1)	(2)	(3)
	$\Delta ln(markup)$	$\Delta ln(sales)$	$\Delta ln(quantities)$
ΔFDI	-0.156**	-0.338***	-0.138
	(0.053)	(0.082)	(0.096)
N	33168	33168	33168
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Polynomial in marginal cost changes	Yes	No	No

Notes. This table reports coefficients from OLS estimations. All regressions include firm and year fixed effects. Column (1) controls for a third order polynomial of changes in marginal costs. ΔFDI denotes horizontal foreign direct investment at the 3-digit industry-level weighted by initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted by initial sales shares of products within firms. $\Delta ln(sales)$ is the logarithm of firm-level sales. $\Delta ln(quantities)$ is the logarithm of firm-level product quantities weighted by initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table 9: Horizontal FDI and product-level outcomes

	(1)	(2)	(3)
	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(marginalcost)$
Panel A: OLS estimation			
ΔFDI (industry)	-0.173***	0.071	-0.244**
	(0.052)	(0.090)	(0.095)
ΔFDI (product)	-0.093***	-0.103*	0.011
	(0.035)	(0.058)	(0.058)
N	131624	131624	131624
Panel B: 2sls estimation			
ΔFDI (industry)	-0.126	2.272***	-2.398***
	(0.496)	(0.778)	(0.893)
ΔFDI (product)	-0.448	-1.219	0.771
	(0.525)	(0.746)	(0.875)
N	127208	127208	127208
Hansen test (p-value)	0.2095	0.0736	0.2837
Firm-product FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes. Panel A reports coefficients from OLS estimations. Panel B reports coefficients from instrumental variable estimations. ΔFDI (industry) denotes horizontal foreign direct investment at the 3-digit industry level. ΔFDI (product) denotes horizontal foreign direct investment at the 12-digit product level. $\Delta ln(price)$ is the logarithm of products' price. $\Delta ln(markup)$ is the logarithm of products' markup. $\Delta ln(marginalcost)$ is the logarithm of products' marginal cost. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table 10: Firm-level heterogeneous effects

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	$\Delta ln(QTFP)$	$\Delta ln(margcost)$	$\Delta ln(QTFP)$	$\Delta ln(margcost)$	$\Delta ln(QTFP)$	$\Delta ln(margcost)$
Sample split	Physical TFP		Revenue TFP		Size	
Panel A: 1st quartile						
ΔFDI	0.023	-0.567**	0.117	-0.084	-0.222	-0.100
	(0.251)	(0.243)	(0.257)	(0.232)	(0.256)	(0.245)
N	8406	8406	8406	8406	8408	8408
Panel B: 2nd quartile						
ΔFDI	0.915***	-0.537**	0.267	-0.341	0.149	-0.346
	(0.238)	(0.242)	(0.275)	(0.257)	(0.287)	(0.256)
N	8266	8266	8266	8266	8266	8266
Panel C: 3rd quartile						
ΔFDI	0.346	-0.423*	0.401	-0.617***	0.622**	-0.284
	(0.258)	(0.252)	(0.283)	(0.225)	(0.289)	(0.240)
N	8337	8337	8337	8337	8336	8336
Panel D: 4th quartile						
ΔFDI	0.153	0.218	0.764**	-0.531**	0.797***	-0.662***
	(0.283)	(0.245)	(0.306)	(0.268)	(0.236)	(0.216)
N	8159	8159	8159	8159	8158	8158
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from OLS estimation. ΔFDI denotes horizontal foreign direct investment at the 3-digit industry-level weighted by initial sales shares of products within firms. $\Delta ln(QTFP)$ denotes the logarithm of physical total factor productivity at the firm-level. $\Delta ln(margcost)$ is the logarithm of firm-level products' marginal cost weighted by initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table 11: Product-level heterogeneous effects

	(1)	(2)	(3)	(4)
Dependent variable	$\Delta ln(marginalcost)$	$\Delta ln(marginalcost)$	$\Delta ln(marginalcost)$	$\Delta ln(marginalcost)$
Sample split	initial marginal cost	initial revenue	initial quality output	initial quality inputs
Panel A: 1st quartile				
ΔFDI_k (industry-level)	-0.096	0.043	-0.101	-0.125
	(0.182)	(0.249)	(0.207)	(0.188)
ΔFDI_j (product-level)	-0.025	-0.047	0.067	-0.079
	(0.110)	(0.149)	(0.115)	(0.111)
N	32906	32929	32791	33107
Panel B: 2nd quartile				
ΔFDI_k (industry-level)	-0.107	-0.352*	0.125	0.077
	(0.158)	(0.191)	(0.191)	(0.167)
ΔFDI_j (product-level)	-0.031	0.020	-0.062	-0.011
	(0.097)	(0.120)	(0.156)	(0.140)
N	32906	32899	33502	38282
Panel C: 3rd quartile				
ΔFDI_k (industry-level)	-0.621***	-0.282*	-0.262	-0.385*
	(0.171)	(0.149)	(0.186)	(0.224)
ΔFDI_j (product-level)	-0.009	0.011	-0.012	0.084
	(0.114)	(0.100)	(0.112)	(0.134)
N	32906	32895	30644	27318
Panel D: 4th quartile				
ΔFDI_k (industry-level)	-0.056	-0.304**	-0.395**	-0.570***
	(0.193)	(0.152)	(0.172)	(0.187)
ΔFDI_j (product-level)	0.022	-0.017	0.069	0.005
	(0.116)	(0.101)	(0.110)	(0.120)
N	32906	32901	31892	32917
Firm-product FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from OLS estimations. ΔFDI_k denotes horizontal foreign direct investment at the 3-digit industry level. ΔFDI_j denotes horizontal foreign direct investment at the 12-digit product level. $\Delta ln(marginalcost)$ is the logarithm of products' marginal cost. Initial quality in column (3) is measured based on Khandelwal et al. (2013). Initial quality in column 4 is based on input price index derived from the physical TFP estimation as explained in section 2.2.1. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

5 Appendix

A: Additional tables

Table A1: Elasticities from production function: Means, *medians*, (standard deviation).

Sector	Observations	Labour	Materials	Capital	RTS
Food, beverages and tobacco	29621	0.24	0.60	0.08	0.93
		0.23	*0.61*	*0.10*	*0.99*
		(0.16)	(0.19)	(0.10)	(0.21)
Textiles, wearing apparel and leather	24067	0.14	0.71	0.16	1.02
		0.15	*0.72*	*0.17*	*1.08*
		(0.11)	(0.10)	(0.07)	(0.19)
Wood, paper products and printing	6385	0.23	0.85	0.01	1.09
		0.21	*0.85*	*0.01*	*1.01*
		(0.17)	(0.11)	(0.16)	(0.21)
Coke, chemicals and pharmaceuticals	58389	0.27	0.69	0.12	1.09
		0.27	*0.69*	*0.12*	*1.08*
		(0.10)	(0.07)	(0.04)	(0.04)
Rubber and plastics	11839	0.23	0.67	0.03	0.94
		0.22	*0.70*	*0.09*	*1.07*
		(0.18)	(0.16)	(0.22)	(0.40)
Non-metallic minerals products	7898	0.28	0.60	0.14	1.02
		0.28	*0.60*	*0.14*	*1.03*
		(0.15)	(0.09)	(0.07)	(0.10)
Basic metal and fabricated metal	27293	0.16	0.76	0.07	1.00
		0.15	*0.76*	*0.06*	*0.98*
		(0.05)	(0.07)	(0.07)	(0.06)
Computers and electronics	10150	0.29	0.71	0.19	1.20
		0.27	*0.71*	*0.16*	*1.12*
		(0.13)	(0.14)	(0.11)	(0.24)
Electricals	11629	0.08	0.87	0.02	0.98
		0.09	*0.88*	*0.08*	*1.07*
		(0.08)	(0.08)	(0.50)	(0.48)
Machinery and equipment	16671	0.31	0.67	0.17	1.16
		0.29	*0.67*	*0.15*	*1.09*
		(0.13)	(0.09)	(0.11)	(0.20)
Motor vehicles and transport equipment	11720	0.29	0.65	0.30	1.25
		0.28	*0.66*	*0.30*	*1.27*
		(0.14)	(0.12)	(0.18)	(0.20)
All manufacturing	215662	0.23	0.69	0.12	1.05
		0.22	*0.70*	*0.12*	*1.06*
		(0.14)	(0.13)	(0.17)	(0.22)

Notes. The table shows output from physical production functions with respect to input quantities. RTS denotes return to scale. Observations denotes the total number of observation used to identify parameters of the production functions.

Table A2: Median markups across industries.

Sector	Observations	Markup
Food, beverages and tobacco	25196	2.18
Textiles, wearing apparel and leather	19797	1.96
Wood, paper products and printing	5564	2.65
Coke, chemicals and pharmaceuticals	50950	2.14
Rubber and plastics	10071	1.78
Non-metallic minerals products	6546	3.67
Basic metal and fabricated metal	23365	2.40
Computers and electronics	8444	2.21
Electricals	10020	2.35
Machinery and equipment	14544	1.93
Motor vehicles and transport equipment	10467	1.76
All manufacturing	184964	2.14

Notes. The table reports the median markup by sector for the sample 1988–2017.

Table A3: Firm characteristics: Means, (standard deviation)

Variables	Definition	Domestic ownership	Foreign ownership
Sales	Income from sales	2754.82	7071.66
		(9333.412)	(16690.742)
Labour	Salaries and wages	174.74	495.32
		(617.122)	(1012.399)
Materials	Expenditure on raw materials	1202.26	2632.91
		(3421.357)	(6033.346)
Capital stock	Gross fixed assets	1684.26	2997.57
		(6112.142)	(7561.173)
No. of products	Product count	2.75	3.26
		(2.415)	(2.785)
Export share	Foreign exchange earnings/sales	0.21	0.16
		(0.296)	(0.272)
TFP	Physical productivity	1.77	1.73
		(1.940)	(2.350)

Notes. The table reports mean values of variable by group. Based on 87,571 and 5,830 firm-year observations of domestic and foreign owned firms, respectively. Monetary variables are measured in Rs. million.

Table A4: List of industries with FDI liberalization

5-digit NIC code	Industry name	Year of liberalization
10792	Coffee curing, roasting, grinding blending etc. and manufacturing of coffee products	2006
11011	Manufacture of distilled, potable, alcoholic beverages such as whiskey, brandy, gin, 'mixed drinks' etc.	2006
11012	Manufacture of country liquor	2006
11019	Distilling, rectifying and blending of spirits	2006
12001	Stemming and redrying of tobacco	2006
12002	Manufacture of bidi	2006
12007	Manufacture of catechu(katha) and chewing lime	2006
12008	Manufacture of pan masala and related products.	2006
12009	Manufacture of other tobacco products including chewing tobacco n.e.c.	2006
20291	Manufacture of matches	2006
20293	Manufacture of essential oils; modification by chemical processes of oils and fats	2006
20296	Manufacture of chemical elements and compounds doped for use in electronics	2006
20299	Manufacture of various other chemical products	2006
21002	Manufacture of allopathic pharmaceutical preparations	2001
21003	Manufacture of 'ayurvedic' or 'unani' pharmaceutical preparation	2001
21004	Manufacture of homeopathic or biochemic pharmaceutical preparations	2001
21006	Manufacture of medical impregnated wadding, gauze, bandages, dressings, surgical gut string etc.	2001
21009	Manufacture of other pharmaceutical and botanical products n.e.c. like hina powder etc.	2001
22112	Manufacture of rubber tyres and tubes for cycles and cycle-rickshaws	2006
22113	Retreading of tyres; replacing or rebuilding of tread on used pneumatic tyres	2006
22119	Manufacture of rubber tyres and tubes n.e.c.	2006
22191	Manufacture of rubber plates, sheets, strips, rods, tubes, pipes, hoses and profile -shapes etc.	2006
22193	Manufacture of rubber contraceptives	2006
22199	Manufacture of other rubber products n.e.c.	2006

Table A5: Exogeneity of India's FDI liberalization reforms - Probit estimation

Panel A	dependent variable: *lib*								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$ln(marketsize)_{t-1}$	0.017								
	(0.042)								
$\Delta ln(marketsize)_{t-1}$		-0.067							
		(0.109)							
$\Delta ln(marketsize)_{t-3}$			-0.074						
			(0.085)						
$capitalintensity_{t-1}$				0.000					
				(0.000)					
$\Delta capitalintensity_{t-1}$					0.000				
					(0.000)				
$\Delta capitalintensity_{t-3}$						0.000			
						(0.000)			
$ln(QTFP)_{t-1}$							-0.055		
							(0.060)		
$\Delta ln(QTFP)_{t-1}$								-0.073	
								(0.057)	
$\Delta ln(QTFP)_{t-3}$									-0.020
									(0.038)
N	622	610	601	622	610	601	622	610	601

Panel B	dependent variable: *lib*								
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
$ln(markup)_{t-1}$	0.014								
	(0.078)								
$\Delta ln(markup)_{t-1}$		-0.016							
		(0.068)							
$\Delta ln(markup)_{t-3}$			-0.037						
			(0.067)						
$ln(price)_{t-1}$				0.023					
				(0.027)					
$\Delta ln(price)_{t-1}$					0.025				
					(0.044)				
$\Delta ln(price)_{t-3}$						0.041			
						(0.028)			
$ln(marginalcost)_{t-1}$							0.020		
							(0.035)		
$\Delta ln(marginalcost)_{t-1}$								0.024	
								(0.044)	
$\Delta ln(marginalcost)_{t-3}$									0.051
									(0.037)
N	616	606	596	622	610	601	616	606	596

Notes. The table reports coefficients from Probit estimations. *lib* denotes FDI liberalization reforms at the 5-digit industry-level. *marketsize* denotes domestic market size measured as the logarithm of total sales aggregated at the 5-digit industry-level. *capitalintensity* denotes capital intensity measured as the ratio between firms' capital value (fixed assets) and wages aggregated at the 5-digit industry-level. $ln(QTFP)$ denotes the logarithm of industry-level firms' physical total factor productivity weighted using firm's share of sales within industries. $ln(price)$, $ln(markup)$ and $ln(marginalcost)$ denote the logarithm of industry-level product price, markups and marginal cost weighted using firm's share of sales within industries. Standard errors are clustered at the five-digit industry level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A6: Exogeneity of India's FDI liberalization reforms - year 2001

Panel A	dependent variable: *lib*								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$ln(marketsize)_{t-1}$	0.003								
	(0.003)								
$\Delta ln(marketsize)_{t-1}$		-0.007							
		(0.011)							
$\Delta ln(marketsize)_{t-3}$			-0.005						
			(0.008)						
$capitalintensity_{t-1}$				0.000					
				(0.000)					
$\Delta capitalintensity_{t-1}$					0.000				
					(0.000)				
$\Delta capitalintensity_{t-3}$						0.000			
						(0.000)			
$ln(QTFP)_{t-1}$							-0.001		
							(0.003)		
$\Delta ln(QTFP)_{t-1}$								-0.004	
								(0.003)	
$\Delta ln(QTFP)_{t-3}$									-0.002
									(0.003)
N	309	302	299	309	302	299	309	302	299

Panel B	dependent variable: *lib*								
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
$ln(markup)_{t-1}$	0.001								
	(0.002)								
$\Delta ln(markup)_{t-1}$		-0.004							
		(0.003)							
$\Delta ln(markup)_{t-3}$			-0.005						
			(0.004)						
$ln(price)_{t-1}$				0.001					
				(0.002)					
$\Delta ln(price)_{t-1}$					0.001				
					(0.003)				
$\Delta ln(price)_{t-3}$						-0.000			
						(0.001)			
$ln(marginalcost)_{t-1}$							0.001		
							(0.002)		
$\Delta ln(marginalcost)_{t-1}$								0.003	
								(0.002)	
$\Delta ln(marginalcost)_{t-3}$									0.003
									(0.002)
N	306	301	299	309	302	299	306	301	299

Notes. The table reports coefficients from linear probability models. *lib* denotes FDI liberalization reforms at the 5-digit industry-level. *marketsize* denotes domestic market size measured as the logarithm of total sales aggregated at the 5-digit industry-level. *capitalintensity* denotes capital intensity measured as the ratio between firms' capital value (fixed assets) and wages aggregated at the 5-digit industry-level. $ln(QTFP)$ denotes the logarithm of industry-level firms' physical total factor productivity weighted using firm's share of sales within industries. $ln(price)$, $ln(markup)$ and $ln(marginalcost)$ denote the logarithm of industry-level product price, markups and marginal cost weighted using firm's share of sales within industries. Standard errors are clustered at the five-digit industry level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A7: Exogeneity of India's FDI liberalization reforms - year 2006

Panel A	dependent variable: *lib*								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$ln(marketsize)_{t-1}$	-0.001								
	(0.005)								
$\Delta ln(marketsize)_{t-1}$		-0.001							
		(0.008)							
$\Delta ln(marketsize)_{t-3}$			-0.006						
			(0.010)						
$capitalintensity_{t-1}$				-0.000*					
				(0.000)					
$\Delta capitalintensity_{t-1}$					0.000				
					(0.000)				
$\Delta capitalintensity_{t-3}$						0.000			
						(0.000)			
$ln(QTFP)_{t-1}$							-0.007		
							(0.008)		
$\Delta ln(QTFP)_{t-1}$								-0.005	
								(0.006)	
$\Delta ln(QTFP)_{t-3}$									-0.001
									(0.004)
N	313	308	302	313	308	302	313	308	302

Panel B	dependent variable: *lib*								
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
$ln(markup)_{t-1}$	0.000								
	(0.013)								
$\Delta ln(markup)_{t-1}$		0.002							
		(0.008)							
$\Delta ln(markup)_{t-3}$			0.001						
			(0.008)						
$ln(price)_{t-1}$				0.002					
				(0.003)					
$\Delta ln(price)_{t-1}$					0.002				
					(0.005)				
$\Delta ln(price)_{t-3}$						0.006			
						(0.004)			
$ln(marginalcost)_{t-1}$							0.002		
							(0.005)		
$\Delta ln(marginalcost)_{t-1}$								0.000	
								(0.005)	
$\Delta ln(marginalcost)_{t-3}$									0.005
									(0.005)
N	310	305	297	313	308	302	310	305	297

Notes. The table reports coefficients from linear probability models. *lib* denotes FDI liberalization reforms at the 5-digit industry-level. *marketsize* denotes domestic market size measured as the logarithm of total sales aggregated at the 5-digit industry-level. *capitalintensity* denotes capital intensity measured as the ratio between firms' capital value (fixed assets) and wages aggregated at the 5-digit industry-level. $ln(QTFP)$ denotes the logarithm of industry-level firms' physical total factor productivity weighted using firm's share of sales within industries. $ln(price)$, $ln(markup)$ and $ln(marginalcost)$ denote the logarithm of industry-level product price, markups and marginal cost weighted using firm's share of sales within industries. Standard errors are clustered at the five-digit industry level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A8: Pro-competitive effects of FDI

	(1)	(2)	(3)
	$\Delta ln(markup)$	$\Delta ln(sales)$	$\Delta ln(quantities)$
ΔFDI	-0.253	-0.947***	-0.384
	(0.261)	(0.096)	(0.426)
N	33168	33168	33168
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Polynomial in marginal cost changes	Yes	No	No

Notes. This table reports coefficients from instrumental variable estimations. All regressions include firm and year fixed effects. Column (1) controls for a third order polynomial of changes in marginal costs. ΔFDI denotes horizontal foreign direct investment at the 3-digit industry-level weighted by initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted by initial sales shares of products within firms. $\Delta ln(sales)$ is the logarithm of firm-level sales. $\Delta ln(quantities)$ is the logarithm of firm-level product quantities weighted by initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A9: First stage results for product-level estimation

	(1)	(2)
	ΔFDI (industry)	ΔFDI (product)
$D(2004) \times POSTlib_{t-2}$	0.018*** (0.004)	-0.022*** (0.006)
$D(2005) \times POSTlib_{t-2}$	0.026*** (0.004)	-0.021*** (0.006)
$D(2006) \times POSTlib_{t-2}$	0.002 (0.004)	-0.025*** (0.006)
$D(2007) \times POSTlib_{t-2}$	-0.007* (0.004)	-0.001 (0.006)
$D(2008) \times POSTlib_{t-2}$	0.083*** (0.004)	-0.007 (0.005)
$D(2009) \times POSTlib_{t-2}$	0.017*** (0.002)	-0.002 (0.003)
$D(2010) \times POSTlib_{t-2}$	-0.006*** (0.002)	0.001 (0.003)
$D(2011) \times POSTlib_{t-2}$	0.024*** (0.002)	0.015*** (0.003)
$D(2004) \times POSTlib_{t-2} \times saleshare_j$	0.010 (0.007)	0.060*** (0.011)
$D(2005) \times POSTlib_{t-2} \times saleshare_j$	0.013* (0.007)	0.099*** (0.011)
$D(2006) \times POSTlib_{t-2} \times saleshare_j$	0.016** (0.008)	0.047*** (0.012)
$D(2007) \times POSTlib_{t-2} \times saleshare_j$	0.018** (0.008)	0.004 (0.012)
$D(2008) \times POSTlib_{t-2} \times saleshare_j$	0.019** (0.007)	0.190*** (0.011)
$D(2009) \times POSTlib_{t-2} \times saleshare_j$	0.000 (0.005)	0.037*** (0.007)
$D(2010) \times POSTlib_{t-2} \times saleshare_j$	0.021*** (0.005)	-0.002 (0.008)
$D(2011) \times POSTlib_{t-2} \times saleshare_j$	0.123*** (0.006)	0.163*** (0.008)
N	127208	127208
First stage F-test	294.81	133.11
Sanderson-Windmeijer test (p-value)	28.56 (0.000)	25.72 (0.000)
Firm FE	Yes	Yes
Year FE	Yes	Yes

Notes. Table reports coefficients from OLS estimation of the first stage. ΔFDI (industry) denotes industry-level changes in horizontal foreign direct investment at the 3-digit industry-level . ΔFDI (product) denotes changes in horizontal FDI at the 12-digit product level. *POSTlib* takes value of one in all years after FDI liberalization in an industry. $D(2004)$ ($D(2005)$... . . . $D(2011)$) takes value of one in the year 2004 (2005...2011). Bootstrapped standard errors are reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A10: Firm-level FE estimation with alternative aggregator (5-digit industry-level)

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
ΔFDI	0.317***	-0.038	-0.175***	0.202**	-0.377***
	(0.109)	(0.043)	(0.066)	(0.087)	(0.099)
N	33168	33168	33168	33168	33168
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from OLS estimations. ΔFDI denotes horizontal foreign direct investment at the 5-digit industry-level weighted using initial sales shares of products within firms. $\Delta ln(QTFP)$ denotes the logarithm of physical total factor productivity at the firm-level. $\Delta ln(RTFP)$ denotes the logarithm of revenue-based total factor productivity at the firm-level measured using Ackerberg et al. (2015) methodology. $\Delta ln(price)$ is the logarithm of firm-level products' price weighted using initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted using initial sales shares of products within firms. $\Delta ln(marginalcost)$ is the logarithm of firm-level products' marginal cost weighted using initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A11: Firm-level FE estimation with alternative aggregator (12-digit product-level)

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
ΔFDI	0.205**	-0.062	-0.046	0.151**	-0.197**
	(0.102)	(0.038)	(0.053)	(0.076)	(0.088)
N	33168	33168	33168	33168	33168
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from OLS estimations. ΔFDI denotes horizontal foreign direct investment at the 12-digit product-level weighted using initial sales shares of products within firms. $\Delta ln(QTFP)$ denotes the logarithm of physical total factor productivity at the firm-level. $\Delta ln(RTFP)$ denotes the logarithm of revenue-based total factor productivity at the firm-level measured using Ackerberg et al. (2015) methodology. $\Delta ln(price)$ is the logarithm of firm-level products' price weighted using initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted using initial sales shares of products within firms. $\Delta ln(marginalcost)$ is the logarithm of firm-level products' marginal cost weighted using initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A12: Firm-level 2sls estimation with alternative aggregators (5-digit industry-level)

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
ΔFDI	1.100**	-0.319	-0.555	0.863**	-1.418***
	(0.467)	(0.218)	(0.341)	(0.415)	(0.526)
N	33168	33168	33168	33168	33168
First stage F-test			182.359		
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from instrumental variable estimations. ΔFDI denotes horizontal foreign direct investment at the 5-digit industry-level weighted by initial sales shares of products within firms. $\Delta ln(QTFP)$ denotes the logarithm of physical total factor productivity at the firm-level. $\Delta ln(RTFP)$ denotes the logarithm of revenue-based total factor productivity at the firm-level estimated by the Ackerberg et al. (2015) methodology. $\Delta ln(price)$ is the logarithm of firm-level products' price changes weighted by initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted by initial sales shares of products within firms. $\Delta ln(marginalcost)$ is the logarithm of firm-level products' marginal cost weighted by initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A13: Firm-level 2sls estimation with alternative aggregators (12-digit industry-level)

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
ΔFDI	1.067**	-0.279	-0.578*	0.971**	-1.549***
	(0.528)	(0.234)	(0.331)	(0.443)	(0.545)
N	33168	33168	33168	33168	33168
First stage F-test			119.172		
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from instrumental variable estimations. ΔFDI denotes horizontal foreign direct investment at the 12-digit product-level weighted by initial sales shares of products within firms. $\Delta ln(QTFP)$ denotes the logarithm of physical total factor productivity at the firm-level. $\Delta ln(RTFP)$ denotes the logarithm of revenue-based total factor productivity at the firm-level estimated by the Ackerberg et al. (2015) methodology. $\Delta ln(price)$ is the logarithm of firm-level products' price changes weighted by initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted by initial sales shares of products within firms. $\Delta ln(marginalcost)$ is the logarithm of firm-level products' marginal cost weighted by initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A14: Firm-level 2sls estimation with controls for tariffs and delicensing

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
ΔFDI	1.171**	-0.320	-0.512	0.939**	-1.451***
	(0.499)	(0.220)	(0.327)	(0.414)	(0.532)
N	33168	33168	33168	33168	33168
First stage F-test			215.009		
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from instrumental variable estimations. Controls for change in tariff and de-licensing are included in all regressions. ΔFDI denotes horizontal foreign direct investment at the 3-digit industry-level weighted by initial sales shares of products within firms. $\Delta ln(QTFP)$ denotes the logarithm of physical total factor productivity at the firm-level. $\Delta ln(RTFP)$ denotes the logarithm of revenue-based total factor productivity at the firm-level estimated by the Ackerberg et al. (2015) methodology. $\Delta ln(price)$ is the logarithm of firm-level products' price changes weighted by initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted by initial sales shares of products within firms. $\Delta ln(marginalcost)$ is the logarithm of firm-level products' marginal cost weighted by initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A15: Firm-level 2sls estimation excluding firms with government ownership

	(1) $\Delta ln(QTFP)$	(2) $\Delta ln(RTFP)$	(3) $\Delta ln(price)$	(4) $\Delta ln(markup)$	(5) $\Delta ln(margcost)$
ΔFDI	1.273***	-0.330	-0.636**	0.838**	-1.474***
	(0.537)	(0.206)	(0.320)	(0.436)	(0.482)
N	31546	31546	31546	31546	31546
First stage F-test			213.291		
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from instrumental variable estimations. ΔFDI denotes horizontal foreign direct investment at the 3-digit industry-level weighted by initial sales shares of products within firms. $\Delta ln(QTFP)$ denotes the logarithm of physical total factor productivity at the firm-level. $\Delta ln(RTFP)$ denotes the logarithm of revenue-based total factor productivity at the firm-level estimated by the Ackerberg et al. (2015) methodology. $\Delta ln(price)$ is the logarithm of firm-level products' price changes weighted by initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted by initial sales shares of products within firms. $\Delta ln(marginalcost)$ is the logarithm of firm-level products' marginal cost weighted by initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A16: Horizontal and vertical foreign direct investment

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
Panel A: WIOD time constant IO tables					
ΔFDI	0.413**	-0.163**	-0.267***	0.229*	-0.496***
	(0.163)	(0.070)	(0.084)	(0.131)	(0.150)
$\Delta back.FDI$	0.887**	0.130	-0.741***	0.182	-0.922***
	(0.370)	(0.157)	(0.178)	(0.283)	(0.333)
$\Delta forw.FDI$	-0.238	-0.524	-0.144	-0.807	0.663
	(1.252)	(0.447)	(0.535)	(0.913)	(1.019)
Panel B: WIOD time variant IO tables					
ΔFDI	0.409**	-0.161**	-0.292***	0.233*	-0.525***
	(0.162)	(0.070)	(0.085)	(0.131)	(0.151)
$\Delta back.FDI$	0.699*	0.152	-0.907***	0.294	-1.201***
	(0.364)	(0.148)	(0.175)	(0.279)	(0.334)
$\Delta forw.FDI$	0.306	-0.149	-1.070**	-0.449	-0.621
	(1.073)	(0.363)	(0.482)	(0.769)	(0.864)
N	19135	19135	19135	19135	19135
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from OLS estimations. Horizontal FDI is measured following equation (14). Backward and forward FDI are measured using equations (15) and equation(16). WIOD refers to the World-Input-Output Database (2016 release). Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A17: Horizontal FDI and similarity of inputs

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
ΔFDI	0.287*	-0.138**	-0.266***	0.008	-0.274**
	(0.153)	(0.059)	(0.076)	(0.118)	(0.139)
$\Delta ISFDI$	0.483	0.168	0.349**	0.679**	-0.330
	(0.332)	(0.159)	(0.168)	(0.274)	(0.304)
N	33168	33168	33168	33168	33168
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes. This table reports coefficients from OLS estimations. ΔFDI denotes horizontal foreign direct investment at the 3-digit industry-level weighted by initial sales shares of products within firms. $\Delta ISFDI$ denotes horizontal foreign direct investment at the 3-digit industry-level weighted by similarity of input index. $\Delta ln(QTFP)$ denotes the logarithm of physical total factor productivity at the firm-level. $\Delta ln(RTFP)$ denotes the logarithm of revenue-based total factor productivity at the firm-level estimated by the Ackerberg et al. (2015) methodology. $\Delta ln(price)$ is the logarithm of firm-level products' price changes weighted by initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted by initial sales shares of products within firms. $\Delta ln(marginalcost)$ is the logarithm of firm-level products' marginal cost weighted by initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A18: FDI spillover effects: non-linear effects

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
ΔFDI	0.376***	-0.108**	-0.202***	0.131	-0.333***
	(0.132)	(0.052)	(0.064)	(0.101)	(0.118)
$\Delta (FDI)^2$	0.788	0.706	1.017	2.459*	-1.442
	(1.770)	(0.817)	(1.020)	(1.477)	(1.770)
N	33168	33168	33168	33168	33168
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes. This table reports coefficients from OLS estimations. ΔFDI denotes horizontal foreign direct investment at the 3-digit industry-level weighted by initial sales shares of products within firms. $\Delta ln(QTFP)$ denotes the logarithm of physical total factor productivity at the firm-level. $\Delta ln(RTFP)$ denotes the logarithm of revenue-based total factor productivity at the firm-level estimated by the Ackerberg et al. (2015) methodology. $\Delta ln(price)$ is the logarithm of firm-level products' price changes weighted by initial sales shares of products within firms. $\Delta ln(markup)$ is the logarithm of firm-level products' markup weighted by initial sales shares of products within firms. $\Delta ln(marginalcost)$ is the logarithm of firm-level products' marginal cost weighted by initial sales shares of products within firms. Bootstrapped standard errors are clustered at the firm-level and reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

B: Production function estimation

Since for single product firms, we do not face the problem of unobserved input allocation across products and can drop the product-specific subscript, the production function becomes:

$$q_{it} = f(\tilde{\boldsymbol{v}}_{it}; \boldsymbol{\beta}) + B(w_{it}, \tilde{\boldsymbol{v}}_{it}, \boldsymbol{\beta}) + \omega_{it} + \epsilon_{it} \tag{18}$$

One can combine $f(.)$ and $B(.)$ into a function $\theta(\tilde{\boldsymbol{v}}_{ijt}, \boldsymbol{c}_{it})$ such that output can be expressed as a function of observable variables and measurement errors: $q_{it} = \theta(\tilde{\boldsymbol{v}}_{it}, \boldsymbol{c}_{it}) + \epsilon_{it}$.

$\theta(.)$ is approximated by a linear combination of all its elements and a polynomial in all continuous variables. While this expression does not identify any parameters of the production and input price functions, it identifies output net of measurement error ϵ_{it} which is denoted by $\hat{\phi}_{it}$. Productivity can then be expressed as:

$$\omega_{it} = \hat{\phi}_{it} - f(\tilde{\boldsymbol{v}}_{it}, \boldsymbol{\beta}) - B(\boldsymbol{c}_{it}, \boldsymbol{c}_{it} \times \tilde{\boldsymbol{v}}_{it}, \boldsymbol{\beta}, \boldsymbol{\delta}) \tag{19}$$

where $\boldsymbol{\delta}$ are the parameters of the input price function to be estimated. LGKP suggests that the function $B(.)$ can additionally be allowed to depend on interactions between input prices and input expenditures. We also followed this alternative modelling procedure, which led to similar estimated production function coefficients. However, it led to collinearity problems in some industries, and we settled on the more parsimonious specification. For identification of parameters, the law of motion for productivity can be used to construct moment conditions:

$$E[\varsigma_{it}(\boldsymbol{\beta}, \boldsymbol{\delta})\boldsymbol{Z}_{it}] = 0 \tag{20}$$

$\boldsymbol{Z}_{it}$ is a vector which includes current values of capital, lagged values of materials and labour and their higher order and interaction terms as they appear in the production function. It further includes lagged values of market shares and prices as well as interactions of lagged prices with lags of production factors and market share. Our initial estimation are undertaken using the GMM procedure suggested by Wooldridge (2009) which is based on moment conditions of the combined error term $\zeta_{it} + \epsilon_{it}$.

For illustration, consider as a simplified example a Cobb Douglas specification. Our modified production function is:

$$q_{it} = \beta_l \tilde{l}_{it} + \beta_m \tilde{m}_{it} + \beta_k \tilde{k}_{it} - \Gamma w(p_{it}, ms_{it}) + \omega_{it} + \epsilon_{it} \tag{21}$$

where $\Gamma = \beta_l + \beta_m + \beta_k$. Productivity is captured by a control function based on inverted factor demand which depends on state variables such as capital and prices. We therefore estimate:

$$q_{it} = \beta_l \tilde{l}_{it} + \beta_m \tilde{m}_{it} + \beta_k \tilde{k}_{it} - \Gamma w(p_{it}, ms_{it}) + \omega_{i,t-1}(k_{i,t-1}, p_{i,t-1}, \hat{pr}_{i,t-1}) + \zeta_{it} + \epsilon_{it} \tag{22}$$

We then use instruments $l_{i,t-1}$, $m_{i,t-1}$, k_{it}, $\hat{pr}_{i,t-1}$, $ms_{i,t-1}$ and lagged values of prices and their interaction with lagged values of inputs.

This estimation procedure yields estimates of $\boldsymbol{\beta}$ and $\boldsymbol{\delta}$, hence, it identifies all parameters from the production and input price functions. We estimate $\boldsymbol{\beta}$ and $\boldsymbol{\delta}$ separately for each industry to allow for industry-specific production technologies and input prices. Under the assumption that $\boldsymbol{\beta}$ and $\boldsymbol{\delta}$ are the same for multi- and single-product firms within industries, input allocations across products within multi-product firms can be recovered which allows estimation of markups and marginal costs for each firm-product-year. Note that as discussed by LGKP, this assumption does not rule out differences in productivity levels between single- and multi-product. Since productivity is modelled to be factor-neutral, differences in TFP do not imply differences in $\boldsymbol{\beta}$ or output elasticities. The approach also allows for TFP to depend on the number of products which can imply (dis)economies of scope. Under the assumption of a common production technology within industries, one can express predicted output as: $\hat{q}_{ijt} = f(\tilde{\boldsymbol{v}}_{ijt}, \boldsymbol{\beta}, \hat{w}_{ijt}, \rho_{ijt}) + \omega_{it}$ and divide the production function into two parts, f_1 and f_2, such that only f_2 depends on input allocations across products. This yields a system of equation for each firm-year which allows identifying productivity ω_{it} for each firm-year and the input share allocation ρ_{ijt} for each firm-product-year:

$$\begin{aligned} \hat{q}_{ijt} - f_1(\tilde{\boldsymbol{v}}_{ijt}, \boldsymbol{\beta}, \hat{w}_{ijt}) &= f_2(\tilde{\boldsymbol{v}}_{ijt}, \hat{w}_{ijt}, \rho_{ijt}) + \omega_{it} \\ \sum_j \exp(\rho_{ijt}) &= 1 \end{aligned} \tag{23}$$

For multi-product firms, we predict $\hat{q}_{ijt}$ from a first stage regression and use parameters $\boldsymbol{\beta}$ and $\boldsymbol{\delta}$ from the sample of single product firms to construct f_1 and f_2. The equation system (23) is then solved numerically for each firm-year. For the Cobb-Douglas case, we solve the equation system:

$$\begin{aligned} \hat{q}_{ijt} - \beta_l \tilde{l}_{it} - \beta_m \tilde{m}_{it} - \beta_k \tilde{k}_{it} &= \omega_{it} + \hat{w}_{ijt} \rho_{ijt} (\beta_m + \beta_l + \beta_k) \\ \sum_j \exp(\rho_{ijt}) &= 1 \end{aligned}$$

See LGKP for the translog case.