Ali, Nesma; Stiebale, Joel

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Foreign direct investment, prices and efficiency: Evidence from India

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Editor:
Prof. Dr. Hans-Theo Normann
Düsseldorf Institute for Competition Economics (DICE)
Tel +49 (0) 211-81-15125, E-Mail normann@dice.hhu.de

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Foreign Direct Investment, Prices and Efficiency: Evidence from India

Nesma Ali Joel Stiebale [1]

July 2021

Abstract

This paper uses a rich panel data set of Indian manufacturing firms to analyze the effects of foreign direct investment (FDI) on various outcomes of domestic firms. We apply recent methodological advances in the estimation of production functions together with detailed product-level information on prices and quantities to estimate physical productivity, markups and marginal costs. Our results indicate the importance of price adjustments which stem from competitive pressure and a pass-through of cost savings to consumers. In line with the previous literature, we find little evidence for 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, such as marginal costs and physical productivity. Exploiting exogenous variation from India's FDI liberalization, we provide evidence that the relationship between exposure to FDI and efficiency is causal. Our results suggest that knowledge spills over across product categories within industries and mainly benefits producers of high-quality products. We also provide evidence that FDI spillovers are stronger for joint ventures and when foreign investors enter via acquisitions.

JEL codes: *F61, F23, G34, L25, D22, D24*
Keywords: *Foreign Direct Investment, Spillovers, Productivity, Marginal Costs, Prices, Markups, Multi-Product Firms*

[1]Nesma Ali: Düsseldorf Institute for Competition Economics (DICE), Heinrich-Heine University Düsseldorf, email: ali@hhu.de; Joel Stiebale: Düsseldorf Institute for Competition Economics (DICE), Heinrich-Heine University Düsseldorf and GEP, University of Nottingham, email: joel.stiebale@hhu.de. This project is funded by the Deutsche Forschungsgemeinschaft (German Research Foundation, DFG), grant number STI 729/1, which is gratefully acknowledged. We would like to thank Maria Garcia-Vega, Sourafel Girma, Johannes Böhm, Ekaterina Kazakova, Richard Kneller, Florian Szücs as well as seminar and conference participants in Delhi, Dublin, Düsseldorf, Göttingen, Nottingham and Trier for helpful comments and suggestions. We would also like to thank Markus Funke, Maximilian Lückemann and Christina Wirths for their excellent research assistance.

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. Foster et al. (2008) demonstrate Smeets and Warzynski (2013) and Garcia-Marin and Voigtländer (2019) demonstrate the importance of distinguishing between revenue and physical productivity in the context of exporters. 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. Interestingly, we find that foreign affiliates are on average not characterized by higher *quantity*-based productivity than domestic firms. However, they seem to be much more profitable due to higher demand, larger markups and superior product quality besides similar levels of marginal costs. This indicates that the competitive advantage of multinational subsidiaries stems from the ability to produce high-quality products 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. This 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.

Moving the analysis to the product-level, we provide evidence that technology spillovers are

[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).

likely to occur across product categories. Reductions in marginal costs at a narrowly defined (12-digit) firm-product-level are associated with 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 but is associated with declining 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.

Finally, we 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).

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 productivity advantage (see Antràs and Yeaple, 2014, for an overview). Within this literature, a

[7]Keller (2010, 2021) argues that the results of this literature have to be interpreted with caution as data on actual supplier-buyer relationships is typically unavailable. Although the direction of the bias from using revenue-based measures of productivity is more obvious for horizontal FDI, estimated spillovers across vertical chains are also affected if changes in demand for intermediate inputs induce changes in input and output prices for domestic suppliers and buyers.

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 data from company balance sheets and profit and loss accounts 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 these 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 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 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] These authors 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_{ijt}^M can be estimated from a production function and α_{ijt}^M 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:

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

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

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

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 $\theta_{ijt}^M = \beta_m$.

[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 product 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) and (5) decompose prices into markups and marginal costs and show that foreign firms charge higher prices due to higher markups while cost differences

[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.

are small and statistically insignificant. Markups and marginal costs are calculated as expressed in equations (2) and (3).

A plausible explanation for higher quantities sold besides higher prices and markups is that foreign-owned firms produce products of higher (perceived) quality. Columns (6) and (7) confirm this hypothesis using the more formal indicators of product quality discussed in section 2.2.2. The fact that there are only small and statistically insignificant differences in marginal costs and physical productivity among the two groups indicates that foreign owned firms advantage lies in producing a high level of quality with relatively low costs.[21] Foreign-owned firms seem on average to be more profitable as indicated by higher revenue TFP and they produce a slightly higher number of products than the average domestic firm. In the next sections, 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 on our measures of revenue, labour, capital, materials and other variables comparing domestic and foreign owned firms at the firm-level. From these, we can note that foreign-owned firms have on average higher sales 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 domestic-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:

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

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.

[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.

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}.

Exposure to FDI at the product and industry-level is measured as the share of sales generated by foreign-owned firms[22]:

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

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

where s_{ijt} (s_{ikt}) denotes sales at the product (industry) level and $foreign_{it}$ is a dummy variable indicating foreign ownership.[23]

To generate a firm-specific measure of FDI exposure, we aggregate FDI at the industry (or 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.[24] 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, as the composition of products can change across years, we use the average of sales shares in t and $t-1$ as weights.

Table 3 reports estimates of different variants of equation (10). In Panel A, one-year differences

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

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

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

are reported. Column (1) indicates that a 1 percentage point increase in exposure to FDI is associated with 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 but close to zero and statistically insignificant (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. In contrast, marginal costs decline to a similar extent as 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 TFP: $\tilde{\omega} = \omega + p$. Hence, lower prices imply lower values of measured revenue TFP.[25] 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

[25] 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.

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 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[26], 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.[27] 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

[26] 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.

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

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.[28] 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.[29] 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 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

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

[29] 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.

with a lag as the association between post-liberalization periods and foreign investor presence seems to increase 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.[30] Column (4) indicates that leads of FDI liberalization periods do not seem to be associated with 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 most of these reforms were implemented 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.[31]

Table 6 shows second stage results of our instrumental variable strategy. The first stage F-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 — is associated with higher physical TFP, lower prices and lower marginal costs of 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 is associated with marginal cost reductions of approximately 1.5%. 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.

The negative relationship between FDI and prices in Indian firms raises the question to which extent domestic firms are crowded out by foreign investors. Table A8 in the Appendix shows results

[30] 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.

[31] 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).

using sales and quantities as outcome variables. Both OLS and IV estimates indicate that foreign presence is associated with a decline in sales of domestic firms. More than two thirds of this decline in sales is due to lower prices and the effects on quantities is not statistically significant. However, if foreign firms would purely generate spillovers without taking demand away from domestic firms, we would expect that quantities of domestic firms would increase when they face lower marginal costs and charge lower prices. It is therefore likely that foreign firms generate both spillovers and competitive pressure on domestic firms.

3.3 Horizontal FDI and product-level outcomes

The results of firm-level regressions indicate that there are spillovers from FDI to domestic firms in the form of higher physical TFP and lower marginal costs which also benefit consumers. 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 7 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 is associated with declining 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 is associated with 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.[32] 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

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

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 categories. However, this is 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 reduced incentives for technology adoption if domestic firms are too far away from the technological frontier (Aghion et al., 2009).

Panel B of Table 7 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). 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.

3.4 Heterogeneous Effects

The results of the two previous subsections show that domestic firms can increase their efficiency when they are exposed to foreign investors and that these gains are also materialized across product categories. In this subsection, we try to understand where these efficiency gains are realized. For this purpose, we estimate heterogeneous effects at the firm- and firm-product-level and differentiate between greenfield investments and M&As and between full and partial foreign ownership.

First, we split firm-level regressions into quartiles according to initial values of size and TFP. Table 8 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. While it might seem surprising that it is not necessarily the most efficient domestic firms that benefit from the presence of foreign investors, it should be kept in mind that foreign investors are not on average physically more productive than domestic firms but they are larger, more profitable and seem to produce products of higher quality (see Table 2).

In Table 9, 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. As the competitive advantage of foreign investors seems to lie in the production of high quality products at relatively low costs (as our results in Table 2 suggest), it seems plausible that technology spillovers are concentrated among domestic firms that specialize in high quality rather than in low-cost firms.

Next, 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&A). 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.[33] 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 10 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&A, 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. 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

[33]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).

results suggest that overall spillovers from FDI are, as expected, indeed mainly driven by firms with partial foreign ownership.

3.5 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 clear 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.[34] As Table A14 shows, our IV results do not change notably when these control variables are added.

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 follow a different objective function. 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

[34]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.

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 experimented with different input-output (IO) tables. First, we constructed our own IO tables from information on raw material inputs in Prowess which can be assigned to industries in a similar way as production outputs. We then calculate α and σ from all observations of single industry-firms pooled over our sample period.[35] As an alternative, we use input-output coefficients from the OECD. We experimented with time-constant IO-weights calculated from the year 2000 to reduce endogeneity problems and time-varying IO weights which are more prone to endogeneity concerns but measure industry-linkages over a sample periods of almost 30 years more accurately. Results in Table A16 indicate positive but imprecisely estimated coefficients for backward and forward spillovers on physical TFP of domestic firms. Most importantly, none of the measures of vertical FDI affects our conclusions regarding the effect of horizontal foreign investment.

As a further check, we also constructed a measure of input similarity following Boehm et al. (2019). 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 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.

[35] Unfortunately, our data does not include information on the allocation of material across products.

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

Finally, 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

This paper analyzes the effects of FDI on various firm- and product-level outcomes of domestic firms in India. Exploiting a data set which includes prices and quantities at the firm-product level, we apply recent advances in the estimation of production functions to estimate markups, marginal costs, and physical productivity. In line with much of the previous literature, especially empirical studies of developing countries, there is little evidence for technology spillovers based on commonly used revenue-based measures of 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 market share of foreign investors, is associated with a 0.25% increase in physical TFP and an approximately 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 is associated with declining 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)
	ln(sales) product	ln(quantity) product	ln(price) product	ln(markup) product	ln(marginal cost) product
Foreign	0.998***	0.750***	0.248***	0.271***	-0.023
	(0.086)	(0.113)	(0.078)	(0.065)	(0.103)
N	165940	165940	165940	165940	165940
Product-year FE	Yes	Yes	Yes	Yes	Yes

	(6)	(7)	(8)	(9)	(10)
	ln(quality) inputs product	ln(quality) outputs product	ln(QTFP) LGKP firm	ln(RTFP) ACF firm	ln(products) count firm
Foreign	0.237***	0.719***	-0.081	0.134***	0.096***
	(0.078)	(0.095)	(0.114)	(0.020)	(0.031)
N	165940	165940	46469	46469	46469
Product-year FE	Yes	Yes	No	No	No
Industry-year FE	No	No	Yes	Yes	Yes

Notes. The table reports coefficients from OLS regressions. Foreign is a dummy variable indicating foreign ownership of at least 25%. Dependent variables in columns 1-7 denote products' sales, quantity, price, markup, marginal cost, and quality. 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. 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 measured using Ackerberg et al. (2015) methodology. 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**	-0.080	-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	0.263**	-0.084*	-0.152**	0.154	-0.306***
	(0.118)	(0.048)	(0.063)	(0.094)	(0.111)
ΔFDI_{t+1}	0.036	-0.039	-0.002	0.045	-0.047
	(0.108)	(0.036)	(0.044)	(0.072)	(0.083)
N	33168	33168	33168	33168	33168
Year FE	Yes	Yes	Yes	Yes	Yes
Panel C: Firm fixed effects					
ΔFDI	0.377***	-0.061	-0.200***	0.136	-0.336***
	(0.132)	(0.052)	(0.064)	(0.100)	(0.118)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	33168	33168	33168	33168	33168
Panel D: 2-years differences					
ΔFDI	0.447***	0.012	-0.226***	0.284**	-0.510***
	(0.160)	(0.060)	(0.077)	(0.126)	(0.151)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	25908	25295	25908	25908	25908
Panel E: 3-years differences					
ΔFDI	0.455**	0.067	-0.105	0.438***	-0.544***
	(0.200)	(0.080)	(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
Year FE	yes	yes	yes	yes	yes
Firm 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**	-0.272	-0.563*	0.903**	-1.466***
	(0.500)	(0.222)	(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: 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
Year FE	Yes	Yes	Yes
Firm-product 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 8: 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	0.016	-0.476**	0.155	-0.097	-0.176	-0.096
	(0.251)	(0.237)	(0.281)	(0.249)	(0.245)	(0.239)
N	8416	8416	8416	8416	8417	8417
Panel B: 2nd quartile						
ΔFDI	0.893***	-0.592**	0.167	-0.677***	0.291	-0.370
	(0.263)	(0.255)	(0.268)	(0.252)	(0.312)	(0.271)
N	8247	8247	8247	8247	8247	8247
Panel C: 3rd quartile						
ΔFDI	0.579**	-0.553**	0.537*	-0.537**	0.464*	-0.171
	(0.246)	(0.236)	(0.288)	(0.251)	(0.280)	(0.250)
N	8334	8334	8334	8334	8333	8333
Panel D: 4th quartile						
ΔFDI	0.282	0.132	0.637**	-0.301	0.867***	-0.663***
	(0.310)	(0.246)	(0.277)	(0.254)	(0.244)	(0.207)
N	8171	8171	8171	8171	8171	8171
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 9: 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_j (industry-level)	-0.096	0.043	-0.101	-0.125
	(0.182)	(0.249)	(0.207)	(0.188)
ΔFDI_k (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_j (industry-level)	-0.107	-0.352*	0.125	0.077
	(0.158)	(0.191)	(0.191)	(0.167)
ΔFDI_k (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_j (industry-level)	-0.621***	-0.282*	-0.262	-0.385*
	(0.171)	(0.149)	(0.186)	(0.224)
ΔFDI_k (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_j (industry-level)	-0.056	-0.304**	-0.395**	-0.570***
	(0.193)	(0.152)	(0.172)	(0.187)
ΔFDI_k (product-level)	0.022	-0.017	0.069	0.005
	(0.116)	(0.101)	(0.110)	(0.120)
N	32906	32901	31892	32917
Year FE	Yes	Yes	Yes	Yes
Firm-product FE	Yes	Yes	Yes	Yes

Notes. The table reports coefficients from OLS estimations. ΔFDI_j denotes horizontal foreign direct investment at the 3-digit industry level. ΔFDI_k 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

Table 10: Spillovers from different entry modes

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
ΔFDI^{MA}	0.357**	-0.009	-0.128*	0.350***	-0.478***
	(0.146)	(0.054)	(0.071)	(0.106)	(0.124)
ΔFDI^{GF}	0.029	-0.246***	-0.209**	-0.322**	0.113
	(0.206)	(0.079)	(0.087)	(0.159)	(0.178)
ΔFDI^{full}	0.141	-0.122**	-0.151**	0.032	-0.183
	(0.125)	(0.055)	(0.065)	(0.105)	(0.118)
ΔFDI^{part}	0.374***	-0.039	-0.153**	0.263***	-0.416***
	(0.134)	(0.054)	(0.067)	(0.116)	(0.101)
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

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 Firm level	Definition	Domestic ownership *number of firm-year*=87571	Foreign ownership *number of firm-year*= 5830
Sales	Income from sales (Rs. million)	2754.82 (9333.412)	7071.66 (16690.742)
Labour	Salaries and wages (Rs. million)	174.74 (617.122)	495.32 (1012.399)
Materials	Expenditure on raw materials (Rs. million)	1202.26 (3421.357)	2632.91 (6033.346)
Capital stock	Gross fixed assets (Rs. million)	1684.26 (6112.142)	2997.57 (7561.173)
No. of products	Product count	2.75 (2.415)	3.26 (2.785)
Export share	Foreign exchange earnings/sales	0.21 (0.296)	0.16 (0.272)
TFP	Physical total factor productivity	1.77 (1.940)	1.73 (2.350)

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 whisky, 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 homoeopathic 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: FDI, sales and quantities

	(1)	(2)	(3)	(4)
	(OLS)	(2SLS)	(OLS)	(2SLS)
	$\Delta ln(fsales)$		$\Delta ln(quantity)$	
ΔFDI	-0.338***	-0.947***	-0.138	-0.384
	(0.082)	(0.365)	(0.096)	(0.426)
N	32378	32378	32378	32378
First stage F-test		159.607		159.607
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Notes. Columns 1 & 3 report coefficients from OLS estimations. Columns 2 & 4 report 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. $\Delta ln(fsales)$ is the logarithm of firm-level sales. $\Delta ln(quantity)$ is the logarithm of firm-level product quantities weighted by initial sales shares of products within firms. Bootstrapped standard errors are 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***	-0.020	-0.175***	0.202**	-0.377***
	(0.109)	(0.042)	(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**	-0.053	-0.046	0.151**	-0.197**
	(0.102)	(0.036)	(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**	-0.257	-0.555*	0.863**	-1.418***
	(0.481)	(0.208)	(0.329)	(0.424)	(0.514)
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**	-0.241	-0.578*	0.971**	-1.549***
	(0.519)	(0.237)	(0.349)	(0.458)	(0.544)
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**	-0.258	-0.512	0.939**	-1.451***
	(0.515)	(0.224)	(0.348)	(0.441)	(0.521)
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***	-0.281	-0.636**	0.838**	-1.474***
	(0.484)	(0.213)	(0.321)	(0.400)	(0.505)
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: Prowess IO tables					
ΔFDI	0.318**	-0.013	-0.205***	0.149	-0.354***
	(0.149)	(0.055)	(0.072)	(0.114)	(0.134)
$\Delta forw.FDI$	0.317	0.035	0.173	-0.053	0.226
	(0.246)	(0.100)	(0.119)	(0.206)	(0.228)
$\Delta back.FDI$	0.104	-0.090**	0.006	-0.023	0.029
	(0.113)	(0.044)	(0.053)	(0.081)	(0.090)
Panel B: OECD time constant IO tables					
ΔFDI	0.361***	-0.062	-0.209***	0.135	-0.344***
	(0.135)	(0.052)	(0.064)	(0.102)	(0.120)
$\Delta forw.FDI$	0.447	0.164	-0.176	-0.201	0.026
	(0.508)	(0.182)	(0.227)	(0.373)	(0.425)
$\Delta back.FDI$	0.231	-0.032	0.244*	0.080	0.164
	(0.273)	(0.102)	(0.136)	(0.220)	(0.249)
Panel C: OECD time variant IO tables					
ΔFDI	0.367***	-0.060	-0.211***	0.133	-0.344***
	(0.134)	(0.052)	(0.064)	(0.102)	(0.120)
$\Delta forw.FDI$	0.718*	0.030	-0.191	-0.078	-0.113
	(0.388)	(0.153)	(0.205)	(0.294)	(0.358)
$\Delta back.FDI$	0.168	-0.017	0.254*	0.068	0.186
	(0.277)	(0.104)	(0.136)	(0.225)	(0.253)
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. Horizontal FDI is measured following equation (14). Backward and forward FDI are measured using equations (15) and equation(16). 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)
	$\Delta ln(QTFP)$	$\Delta ln(RTFP)$	$\Delta ln(price)$	$\Delta ln(markup)$	$\Delta ln(margcost)$
$\Delta ISFDI$	-0.115	0.280*	0.187	0.243	-0.056
	(0.349)	(0.157)	(0.164)	(0.279)	(0.297)
ΔFDI	0.398***	-0.112*	-0.234***	0.092	-0.325**
	(0.146)	(0.057)	(0.070)	(0.117)	(0.137)
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***	-0.064	-0.202***	0.131	-0.333***
	(0.132)	(0.052)	(0.064)	(0.101)	(0.118)
$\Delta (FDI)^2$	0.788	1.390*	1.017	2.459*	-1.442
	(1.770)	(0.823)	(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. $\Delta ISFDI$ 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

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.

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Heinrich-Heine-Universität Düsseldorf

Düsseldorfer Institut für Wettbewerbsökonomie (DICE)

Universitätsstraße 1, 40225 Düsseldorf

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