Does input-trade liberalization affect firms' foreign technology choice?

Maria Bas, Antoine Berthou

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Abstract: This paper studies the impact of input-trade liberalization on firms' decision to upgrade foreign technology embodied in imported capital goods. Our empirical analysis is motivated by a simple theoretical framework of endogenous technology adoption, heterogeneous firms and imported inputs. The model predicts a positive effect of input tariff reductions on firms' technology choice to source capital goods from abroad. This effect is heterogeneous across firms depending on their initial productivity level. Relying on India's trade liberalization episode in the early 1990s, we demonstrate that the probability of importing capital goods is higher for firms producing in industries that have experienced greater cuts on tariffs on intermediate goods. Only those firms in the middle range of the initial productivity distribution have benefited from input-trade liberalization to upgrade their technology.

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I.INTRODUCTION

Trade liberalization has produced in the past two decades steady growth in imports of intermediate and capital goods across countries. The endogenous-growth literature has provided theoretical arguments for the role of foreign intermediate inputs in enhancing economic growth and productivity gains (Ethier, 1979, 1982; Grossman and Helpman, 1991; Rivera-Batiz and Romer, 1991).[2] The specific influence of trade in capital goods on economic growth has also been emphasized in a number of theoretical and empirical works (Lee, 1995; Eaton and Kortum, 2001; Goh and Olivier, 2002). Importing capital goods is found to be a relevant channel of foreign technology transfers and R&D spillovers across countries (Xu and Wang, 1999). Trade liberalization is therefore expected to improve economic growth, by decreasing the cost of both foreign intermediate goods and capital equipments (Amiti and Konings, 2007; Topalova and Khandelwal, 2011; Goldberg et al., 2010; Eaton and Kortum, 2001).

This paper investigates the link between input-trade liberalization and foreign technology adoption embodied in imports of capital goods. Input-trade liberalization may affect technology adoption through a *direct* channel: the reduction of tariffs on capital goods decreases their price and allows firms to import a larger volume of these goods. In this work, we take a different perspective and focus on an *indirect* channel. We look at the effect of tariff cuts affecting variable inputs on firms' decision to upgrade foreign technology in imported capital goods. We emphasize unexplored mechanisms through which trade liberalization affects firms' technology choice: a supply shock of input tariff reductions and a complementarity channel between imported variable intermediate goods and capital equipment. Such complementarity is observed in our micro-data of Indian firms used in the empirical analysis. We first show that only a subset of firms in our sample import capital goods and almost all of them also import intermediate inputs. This feature of the data suggests that importing capital goods is associated

[2]Recent firm-level studies have confirmed that input-trade liberalization played a key role on firm productivity growth (Schor, 2004; Amiti and Konings, 2007; Topalova and Khandelwal, 2011), the ability to introduce new products in the domestic market (Goldberg et al., 2010), export performance (Bas, 2012; Bas and Strauss-Kahn, 2015) and mark-ups changes (DeLoecker et al., 2016). Other works highlight a positive link between imports of intermediate goods and firm productivity (Kasahara and Rodrigue, 2008; Halpern et al., 2015).

with a technological investment decision. Moreover, these firms that import both intermediate inputs and capital equipment goods improve their productivity gains suggesting a complementarity between imported inputs and foreign technology in the production process.

Our empirical analysis is motivated by a simple model of heterogeneous firms, endogenous technology adoption and imported inputs that captures these main features of the Indian data. The aim of the theoretical model is to rationalize the channels through which input-trade liberalization affects firms' decision to upgrade foreign technology embodied in imported capital goods. Input-trade liberalization reduces the costs of imported intermediate inputs and allows firms to decrease their marginal costs and increase their profitability. In the presence of fixed cost of technology adoption, heterogeneous firms and complementarity between imported inputs and high-foreign technology, the model yields two main testable implications. First, input tariff reductions increase the probability of importing capital goods. Second, the effect of input-trade liberalization on firms' technology choice is heterogeneous across firms depending on their initial productivity level. Firms that will benefit from input-trade liberalization are those with a high productivity level using low-technology embodied in domestic capital goods before input tariff cuts.

We then test the model implications using the Indian firm-level dataset, Prowess, over the 1989-1997 period. This data was collected by the Centre for Monitoring the Indian Economy (CMIE). The Prowess dataset provides information on imports distinguished by type of goods (capital equipment, intermediate goods and final goods). To establish the causal link between the availability of imported intermediate goods and firms' decision to import capital goods, we rely on the unilateral trade reform that took place in India at the beginning of the 1990s as a part of the 'Eighth Five-Year Plan'.[3] We depart from previous studies of input-trade liberalization by distinguishing tariffs on variable inputs from tariffs on capital equipment products. The empirical identification strategy disentangles the direct effects of tariffs on capital goods and the indirect effects of tariffs on other variable intermediate goods on firms' decision

[3]Section 5.2 describes the policy instruments applied by the Indian Government during this reform.

to import capital equipment goods from abroad. Using effectively applied most favorite nation (MFN) tariffs data and input-output matrix, we construct tariff measures on variable inputs and on capital goods separately. We first present evidence that our tariff measures are free of reverse causality concerns. We extend the previous works in the literature and show that input tariff changes are uncorrelated with initial firm and industry characteristics relevant for our analysis during the trade reform under the 'Eighth Five-Year Plan'. We then exploit this exogenous variation in input tariffs across industries to identify the effect of the availability of foreign variable intermediate goods on firms' decision to import capital goods taking into account changes in specific tariffs on capital goods.

The empirical findings confirm the theoretical predictions. Firms producing in industries with larger input tariff cuts have a higher probability of importing capital goods. Our results imply that the average input tariff reductions during the 1989-1997 period, 27 percentage points, is estimated to produce a 4.6 percent increase in the probability of importing capital goods for the average firm importing intermediate goods. These results take into account the direct effect of capital goods tariff changes. We then investigate if the impact of input-trade liberalization is heterogeneous across firms. Only those firms in the middle range of the productivity distribution import capital goods after input tariff reductions. Firms in the middle range of the initial productivity distribution increase their probability of sourcing capital goods by almost 10 percent. As predicted by the model, our findings suggest that the least productive firms do not benefit from input tariff cuts to upgrade foreign technology. Input tariff changes do not affect either the most productive firms that might have already adopted the foreign technology before input tariff cuts.

These results are robust to specifications which control for industry and firm observable characteristics that could be related to tariff changes and might change over time. We also take into account other possible explanations related to the incentives of Indian firms to adopt foreign technology. We show that our results remain robust when we explicitly control for other reforms that took place in India, foreign demand shocks (export-channel) and changes in firms' financial health that also affect firms' decision to import capital goods. Our findings are also robust and stable to other sensitivity tests. First, we investigate if reductions on tariff on intermediate goods are associated with the decision to start sourcing capital goods from abroad when we restrict our sample to firms that have not imported capital goods in the previous years. Second, the previous findings remain also stable when we exclude foreign or state-owned firms from the sample. Finally, we also find a positive effect of input-trade liberalization on the intensive margin of imports of capital goods.

These findings contribute to the literature on trade liberalization and firms' technology choice. Most of the existent theoretical studies focus on the effects of foreign demand shocks on firms' technology or quality upgrading. They look at demand shocks related to final goods tariff changes affecting exports in bilateral trade agreements or expansion of other export opportunities (Yeaple, 2005; Verhoogen, 2008; Bustos, 2011; Aw et al., 2011; Lileeva and Trefler, 2010; Costantini and Melitz, 2008; Bas and Ledezma, 2015). The contribution of this paper to this literature is to focus on an unexplored channel through which trade liberalization might also affect firms' technology choice, namely, a supply shock related to changes in the costs of imported intermediate inputs. Changes in tariffs on intermediate goods might affect firms' performance and thereby, firms' technology upgrading decision through multiple mechanisms: reduction of production costs, foreign technology transfer and complementarity between imported intermediate inputs and high-technology. Our findings show that input tariffs changes are also an important factor to explain firms' technology choice.

Our results also complete the existing evidence regarding the microeconomic effects of input-trade liberalization on firm performance. Concerning the case of India, input tariff cuts have contributed significantly to firm productivity growth and also to the ability of firms to introduce new products. Topalova and Khandelwal (2011) show that input-trade liberalization improved firm productivity by 4.8 percent in India, while Goldberg et al. (2010) demonstrate that input-tariff cuts in India account on average for 31 percent of the new products introduced by domestic firms. They also show evidence of the direct effect of import tariff cuts on intermediate inputs in India during the same period under analysis. They find that tariff declines have a more pronounced impact on the extensive margin of imported intermediate products relative to final goods. DeLoecker et al. (2016) show that trade liberalization reduces prices and that output tariff cuts have pro-competitive effects. They find that price reductions are small relative to the declines in marginal costs due to the input-tariff liberalization. Recent studies focused on the role of input-trade liberalization in shaping firms' export performance. Using firm-level data from Argentina, Bas (2012) finds that firms producing in industries with larger input-tariff cuts have a greater probability of entering the export market. Bas and Strauss-Kahn (2015) show that Chinese firms that have benefited from input tariff cuts bought more expensive inputs and raised their export prices. These findings suggest that input-trade liberalization induces firms to upgrade their inputs at low cost to upgrade the quality of their exported products.

The next section describes the main empirical facts on Indian firms importing intermediate inputs and capital equipment goods. Section III presents a simple theoretical framework of endogenous foreign technology adoption that reflects the main features of the data and rationalizes the mechanisms through which input-trade liberalization affects firms' decision to upgrade technology. Section IV describes the testable empirical implications. Section V presents the trade-policy background in India, the estimation strategy and the empirical results. Section VI explores alternative explanations. Section VII introduces several robustness tests. The last section concludes.

II. EMPIRICAL MOTIVATION

Before analyzing the relationship between input-trade liberalization and firms' decision to upgrade foreign technology embodied in imported capital goods, this section provides a first inspection of the data. We document several empirical facts on firms sourcing intermediate inputs and capital equipment goods from foreign countries that will guide the assumptions of our theoretical model.

Only a small subset of Indian firms produces with foreign technology embodied in imported capital goods. During the period 1989-1997, only 38 percent of firms in the sample import capital goods, while most of the firms (73 percent) import intermediate goods. Moreover, firms import intermediate inputs on yearly basis, while firms import capital goods more sporadically. Looking at the firms that source both foreign goods reveals that almost all firms that import capital goods (99 percent) also purchase imported intermediate goods. The fact that only half of the firms that import intermediate goods are able to source imported capital equipment goods suggests that the decision to source capital goods from abroad is related to a technological choice that involves a fixed investment cost.[4]

Empirical fact 1: A large proportion of firms imports intermediate goods, while only a subset of those firms also imports capital equipment goods.

This small subset of firms that produces with imported capital goods technology performs better than non-importers of capital equipment goods. Table 1 shows estimations of importer premia of capital goods. We regress firms' sales, capital stock, wage-bill, profits and the share of imported inputs (imports of intermediates over total inputs) on a dummy variable equal to one for firms with positive values of imports of capital goods (importer of capital goods) and zero for those firms that do not import (non-importer of capital goods), including industry and year fixed effects. The results show that within an industry-year, firms that import capital goods have larger sales, capital stock, wage-bill, profits and imported input share

Table 1 about here

Empirical fact 2: Firms producing with foreign technology embodied in imported capital goods have larger sales, capital stock, are more profitable and have a higher share of imported inputs than non-importers of capital goods.

[4]Using detailed product-level data on imports by Indian manufacturing plants, Fernandes et al. (2012) show the existence of fixed costs of importing.

We also observed that imports of intermediates and capital goods are positively correlated. Firms that import intermediate inputs have a greater probability to source capital equipments from foreign countries. Table 2 presents a set of simple estimations of the probability of importing capital equipment goods as a function of firms' imported inputs intensity (the ratio of imported inputs over total inputs). We look at the relationship between the decision to import capital goods and the imported input intensity of the firm across firms within the same 3-digit industry (columns 1 and 2) and within-firm over time (columns 3 and 4). Column (1) suggests that comparing firms producing in the same industry, firms that import intermediate goods are more likely to import capital equipment goods. Column (2) includes a control variable of firm size (wage-bill).[5] Looking at within-firm variation over time, columns (3) and (4) show that the decision to upgrade foreign technology embodied in imported capital goods is positively correlated with firms' imported input intensity. This descriptive evidence suggests that there exists a certain complementarity between imported capital goods and intermediate inputs in India.

Table 2 about here

Empirical fact 3: The decision of sourcing capital goods from abroad is positively correlated with imports of intermediate goods.

As a final step, we explore if this complementarity between foreign technology and imported intermediate goods translates into a higher global efficiency of the firm in the production process. We investigate if importing both capital and intermediate goods improves firms' total factor productivity (TFP) by estimating a production function relying on the methodology developed by Levinsohn and Petrin (2003) (henceforth LP). The LP approach controls for simultaneity bias in the estimation of firms' production function.[6] LP is based on Olley and Pakes (1996) methodology that develop a two-stage

[5] We rely on wage-bill as a measure of firms' size since total employment is not reported in the Prowess dataset.

[6] Simultaneity arises because firms' variable input demands and unobserved productivity are positively correlated: the firm-specific productivity is known by the firm but not by the econometrician and firms respond to productivity shocks by modifying their purchases of variable inputs.

method to control for unobserved firm productivity.[7] We modify the LP-OP estimation by incorporating the importer status of capital goods and intermediate inputs in the production function estimation. We also control for the volume of imports of capital goods and/or intermediates to avoid that importer status pick up the fact that firms that import both goods capital and intermediates will tend to have a larger volume of imports that can affect total efficiency.[8] Table A1 in the online appendix reports the results. In column (2) we include the dummy variables indicating whether the firm imports only intermediates or both inputs and capital equipment goods. Firms producing with foreign inputs and domestic capital goods have greater TFP relative to firms using only domestic inputs (18 percent). The estimates also show that firms producing with both foreign inputs and imported capital goods are 22 percent more productive than non-importers.[9]

Empirical fact 4: Producing with both imported inputs and foreign capital equipment goods improves firms' global efficiency in the production process.

Given such complementarity, input-trade liberalization should affect firms' decision to upgrade foreign technology in imported capital goods. The average tariff on variable imported intermediate goods fell 27 percentage points between 1989 and 1997.[10] At the same time that input tariffs drop, the share of firms importing capital equipment goods increases in most industries. As can be seen in Figure A1 (in the online appendix) within each 2-digit industry, the highest input tariffs drop and the greatest expansion of the share of capital goods importers occur at the same time.

Empirical fact 5: As average input tariff fall, the share of firms importing capital goods increase.

[7] Levinsohn and Petrin (2003) build upon the idea of Olley and Pakes using primary input demand (electricity) instead of the investment decision to control for unobserved productivity shocks. Their rationale lies in the idea that investment data are often missing or lumpy, whereas data on raw inputs are of better quality thus guaranteeing strict monotonicity without efficiency loss. The Prowess dataset reports information on electricity inputs so we rely on the LP methodology.

[8] We thank an anonymous referee for suggesting this control variable.

[9] Note that this evidence gives just an empirical motivation of the model assumption of complementarity between imported capital goods and intermediate inputs. Although the production function is estimated pooling industries, the estimation includes 3-digit industry fixed effects.

[10] Input tariffs are computed as tariff on variable intermediate goods other than capital equipment goods at the 3-digit industry level as described in section 5.1.

The next section develops a simple model that rationalizes these empirical facts to explain the role of input-trade liberalization on firms' decision to upgrade foreign technology embodied in imported capital goods.

III. THEORETICAL MOTIVATION

Previous models of heterogeneous firms and technology or quality upgrading focus on the impact of foreign demand shocks, mainly through export variable cost changes, on firms' decision to upgrade their technology/quality. Yeaple (2005) develops a trade model of heterogeneous skills, technology choice and ex-post heterogeneous firms. In this model, trade liberalization by a reduction of trade variable costs enhances technology adoption and skill-upgrading. Verhoogen (2008) presents a model of firm heterogeneity and quality differentiation, where more productive firms produce high quality goods to the export market. Expansion of export opportunities leads more-productive firms to upgrade the quality of their goods for the export market. Bustos (2011) builds on Yeaple (2005) and Melitz (2003) to develop a trade model of heterogeneous firms and endogeneous technology adoption. In her model trade variable cost reductions increase expected export revenues and enhance technology upgrading. Bas and Ledezma (2015) extends Melitz (2003) model by including an additional stage of investment choice over a continuous support that determines firm productivity. In this model, trade liberalization also affects investment choice and productivity through an expansion of foreign demand. Other works that include fixed costs of innovation or technology upgrading in a Melitz-type model are Aw et al. (2011); Lileeva and Trefler (2010); Costantini and Melitz (2008). In those models, trade liberalization also shapes technology choice via a foreign demand channel through changes in trade variable costs affecting final goods.

Our model is also related to Kugler and Verhoogen (2011) who extend Melitz (2003) heterogeneous firms model to include an endogenous input and output quality choices. They add a domestic intermediate-input sector that produces inputs of different qualities. They consider two scenarios. In the first one, input quality and firm capability draws are complements to generate output quality. In the second scenario, they assume fixed costs of quality upgrading and that producing high-quality output requires high-quality inputs.[11] Only in this second scenario, firms' quality choice depends on the scale of market to which the plant sells. This second variant of the model will then predict that an exogeneous increase in market access induces quality-investments.[12] Given that inputs are only domestically produced, trade liberalization will not affect production factor costs.

We depart from these models of trade, heterogeneous firms and technology/quality upgrading that focus on foreign demand shocks related to final goods trade variable cost changes and expansion of market access. Our focus relies instead on a supply shock, namely variations in the relative production costs associated to input-trade liberalization. Assuming that firms produce their final product with both domestic and imported intermediate inputs and that high-technology is biased towards foreign inputs, trade liberalization through input tariff reductions affects the relative costs of foreign inputs and thereby, firms' profitability and the incentives for technology adoption. Kasahara and Lapham (2013) also introduce in a Melitz-type model imported intermediate goods and fixed cost of importing to investigate the simultaneous choice of export final goods and import intermediates. Amiti and Davis (2012) build on Kasahara and Lapham (2013) to explain the effects of input- and output-trade liberalization on firms' wages. Bombarda and Gamberoni (2013) develop a Melitz-type model including an intermediate goods sector producing differentiated varieties for domestic and foreign markets to explain the impact of relaxing rules of origin. However, they assume that intermediate goods producers are trade frictionless. These models do not take into account how imported inputs tariffs affect firms' technology choice.

Our model is closely related to the recent framework developed by Boler et al. (2015) of heterogeneous firms, endogenous R&D choice and international sourcing of intermediate goods. In their setting

[11] Hallak and Sivadasan (2013) also consider fixed costs of quality upgrading. They develop a model of trade with two dimensions of firm heterogeneity (productivity and caliber, the ability of to develop high quality products with lower fixed outlays). In this model, exporters have more incentives to invest in quality upgrading due to a higher total demand and because trade costs decrease with quality. Thereby, trade liberalization enhances quality upgrading.

[12] For simplicity the authors assume that there are no trade variable costs.

the complementarity mechanism between imported inputs and R&D investments arise due to a scale effect: on the one hand, lower R&D costs raise the average productivity and firm size increasing the number of imported inputs and on the other hand, importing intermediate goods reduce marginal costs making it easier to incur the fixed costs of R&D. In the empirical analysis they test the first implication by exploiting the implementation of a R&D tax credit in Norway and show that this reform stimulates not only R&D investments but also imports of intermediates, which contributed to productivity growth. Our focus is instead on how input-trade liberalisation affects firms' foreign technology choice embodied in imported capital goods. Assuming that foreign technology is biased towards imported intermediates and the existence of fixed costs of importing capital goods, we show that input-trade liberalization fosters foreign technology adoption and the effect of input-tariff cuts is heterogeneous across firms depending on their initial productivity level. Since we want to emphasize this imported input channel, for the sake of simplicity we abstract from the export side of the story and the effects of trade liberalization through variations in trade variable costs affecting final goods that are already well-documented in the literature.

Set-up of the model

The aim of this section is to motivate our empirical analysis by introducing a simple model of heterogeneous firms, endogenous technology adoption and imported inputs based on Melitz (2003). The assumptions of the model capture the empirical facts described in the previous section. The theory rationalizes the mechanisms through which input-trade liberalization affects firms' decision to upgrade technology embodied in imported capital equipement goods.

Preferences. The representative household allocates consumption from among the range of differentiated varieties of final goods ω . Consumer preferences are assumed to take the Constant Elasticity of Substitution (CES) utility function: $U = \left[\int_{\omega\in\Omega} q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega\right]^{\frac{\sigma}{\sigma-1}}$, where $\sigma > 1$ is the elasticity of substitution between two varieties and Ω the set of available varieties. The optimal demand function for each differentiated variety is given by: $q(\omega) = Q\left[\frac{p(\omega)}{P}\right]^{-\sigma}$, where $Q \equiv U$ is the aggregate consumption of available varieties, P the price index and $p(\omega)$ the price set by a firm. $R = PQ$, aggregate revenue. The price index dual to the CES utility function is $P = \left[\int_{\omega\in\Omega} p(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}}$.

Production

There are two sectors in the economy. One sector produces a homogeneous domestic constant-return-to-scale intermediate-input x_d with one unit of labor requirement under perfect competition. Labor is inelastically supplied and the wage is used as a numeraire. This homogeneous intermediate goods sector is characterized by perfect competition, so that the price of domestic inputs equals the marginal cost of producing the input: $p_x = w = 1$. Similar to previous works on heterogeneous firms and imported intermediate goods (Kasahara and Lapham (2013) and Amiti and Davis (2012)), we assume that intermediate goods are available in the country in fixed measure exogenously determined.[13] This sector also produces domestic capital equipment goods k_d under perfect competition and constant-return-to-scale using one unit of labor requirement. The price of domestic capital goods is then equal to one.

The other sector produces a continuum of differentiated final goods under monopolistic competition. In this sector, there is a continuum of firms, which are all different in terms of their initial productivity level φ. Each firm produces a distinct horizontally-differentiated variety of final good in a monopolistic competition market structure. The production of each variety of final good q involves a fixed production cost f in terms of labor.[14] Firms combine intermediate inputs x and capital equipment goods k to produce the final good in a Cobb-Douglas technology with factor shares η and $1-\eta$: $q(\varphi) = \varphi x^{\eta} k^{1-\eta}$. Firms produce using both domestic x_d and imported x_m inputs combined in a CES function with an elasticity of substitution between the two types of inputs equal to $\theta = \frac{1}{1-\alpha}$. Domestic and imported inputs are

[13] This assumption of a fixed measure of intermediate goods allows us to focus on the cost-reduction channel of intermediate goods trade in a tractable way avoiding the possible multiple equilibriums of models like Venables (1996).

[14] This assumption allows us to study the decision of firms that face homogeneous fixed costs.

imperfect substitutes, $0 < \alpha < 1$ and $1 \leq \theta \leq \infty$. To keep the model simple, we assume that all firms used both intermediate goods. This assumption is in line with the empirical fact 1 described in the previous section.

$$x = (x_{di}^{\alpha} + \gamma_i^{\alpha} x_{mi}^{\alpha})^{\frac{1}{\alpha}} \qquad for \;\; i = \{l, h\} \tag{2}$$

Firms can produce the final good with a low- or a high-technology with subscripts l and h. Low-technology is embodied in domestic capital goods k_d and is available to all firms. High-technology is characterized by imported capital goods k_m and implies incurring an additional fixed technology adoption cost f_h in terms of labor.[15] Empirical fact 1 suggests that sourcing capital equipment goods from abroad in India involves a fixed investment cost that only a few firms can afford. The fixed cost of importing capital goods represents an investment in a new and more advanced technology that reduces marginal costs of production. The parameter γ_i represents the complementarity between imported intermediate inputs and imported capital goods (empirical facts 3 and 4). The high value of this factor is only available to firms that pay the fixed foreign technology cost. Therefore, firms producing with high-technology embodied in imported capital goods combine both types of capital goods by a Cobb-Douglas function $k = k_m^{\beta} k_d^{1-\beta}$ and increase their efficiency due to the complementarity in the production process between imported inputs and imported capital goods with $\gamma_h > 1$. Firms producing only with low-domestic-technology have $k = k_d$ and $\gamma_l = 1$. The complementarity between imported inputs and imported capital goods yields to a higher efficiency in the production process reducing firms' marginal costs. This complementarity translates in an imported-input biased foreign-technology.[16] Given that imported and domestic intermediate goods are imperfect substitutes, the complementarity assumption im-

[15]The assumption that the fixed technology adoption cost is also measured in terms of labor allows us to study the technology choice of firms that face homogeneous fixed costs.

[16]Note that this complementarity is similar to the one present in the trade-induced skilled-biased technological change models. The main difference is that such models do not explain supply shocks driven by trade liberalization and associated with changes in the price of production factors. They focus instead on demand side shocks related to trade variable costs reductions in final goods that increase firms' output demand and then the relative demand of skilled-labor.

plies that firms producing with high-technology embodied in imported capital goods are imported-input intensive and firms producing with low-technology represented by domestic capital goods are domestic-input intensive. The evidence presented on the previous section suggests that imported intermediate inputs are complementary with foreign technology embodied in imported capital goods for Indian firms.

Each firm chooses its price to maximize its profits subject to a demand curve with constant elasticity σ. The equilibrium price reflects a constant markup over marginal cost:

$$p_i(\varphi) = \frac{\sigma}{\sigma - 1}\frac{c_i}{\varphi} \tag{3}$$

In this model, marginal cost can be divided into an intrinsic productivity term φ and a cost index c_i, which combines the prices of intermediate and capital goods. Final good producers are price-takers in intermediate-input and capital equipment goods markets. The price of imported inputs and capital goods takes into account the input tariff τ_m and the capital goods tariff τ_k, respectively. Since the price of domestic intermediate and capital goods is equal to the wage which is used as a numeraire, the cost index for the low- and high-technology firms can be expressed as a function of the complementarity parameter, input and capital goods tariffs: $c_l = \left(1 + \tau_m^{\frac{\alpha}{\alpha-1}}\right)^{\frac{\eta(\alpha-1)}{\alpha}}$ and $c_h = \tau_k^{\beta(1-\eta)}\left(1 + \left(\frac{\tau_m}{\gamma_h}\right)^{\frac{\alpha}{\alpha-1}}\right)^{\frac{\eta(\alpha-1)}{\alpha}}$. High-technology firms pay a fixed technology cost that allows them to reduce their marginal cost by increasing their efficiency through the complementarity between imported inputs and imported capital goods (γ_h). We assume that the efficiency parameter of imported capital goods γ_h is higher than its additional variable cost τ_k. The cost index of high-technology firms c_h is then lower than the one of low-technology firms c_l. The ratio $\frac{c_h}{c_l}$ is determined by:

$$\frac{c_h}{c_l} = \tau_k^{\beta(1-\eta)}\left(\frac{\tau_m^{\frac{\alpha}{1-\alpha}} + 1}{\tau_m^{\frac{\alpha}{1-\alpha}} + \gamma_h^{\frac{\alpha}{1-\alpha}}}\right)^{\frac{\eta(1-\alpha)}{\alpha}} \tag{4}$$

This ratio expresses the relative cost of high-technology firms to low-technology firms. The relative cost $\frac{c_h}{c_l}$ is an increasing function of input tariffs. Partially differentiating equation (4) with respect to the input tariffs (τ_m), we find that $\partial \frac{c_h}{c_l} / \partial \tau_m > 0$ since $0 < \alpha < 1$ and $\gamma_h > 1$. The lower the input tariffs the lower the relative unit costs of firms using the high-technology vis-a-vis low-technology firms. This result is explained by the fact that using high-technology in imported capital goods improves the efficiency of production through the use of foreign inputs. Adopting the high-technology induces a technical change that is biased towards the use of foreign inputs given the substitutability between domestic and imported intermediate goods in the CES production function. This makes the production process more sensitive to input tariff changes. The relative cost $\frac{c_h}{c_l}$ is also an increasing function of capital goods tariffs. A reduction of tariffs on capital goods reduces the relative costs of using high-foreign technology.

The ratio of the relative high-technology unit cost to low-technology expressed in equation (4) is the key variable in this model that captures the differential effect of input-tariff changes on firms' revenues and profits. Combining the demand and the price function, firms' revenues are given by $r_i(\varphi) = \left(\frac{P}{p_i(\varphi)}\right)^{\sigma-1} R = A c_i^{1-\sigma} \varphi^{\sigma-1}$, where R is the aggregate revenue and $A = P^{\sigma-1} R \left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1}$ is an index for market demand. High-technology firms' revenues can be written as a function of revenues of low-technology firms $r_h(\varphi) = r_l \left(\frac{c_h}{c_l}\right)^{1-\sigma}$. Hence, firms that upgrade technology importing capital goods have a relative cost advantage that allows them to raise their revenues by the term $\left(\frac{c_h}{c_l}\right)^{1-\sigma}$. Note that this term is higher than one since the elasticity of substitution among final goods is $\sigma > 1$ and $c_l > c_h$. Profits for both types of firms are given by $\pi_l(\varphi) = \frac{r_l(\varphi)}{\sigma} - f$ and $\pi_h(\varphi) = \frac{r_l(\varphi)\left(\frac{c_h}{c_l}\right)^{1-\sigma}}{\sigma} - f - f_h$.

Given that the price is a constant mark-up over marginal costs, in this model firms with a higher productivity draw using high-technology set lower prices than low-technology firms due to a better exogenous productivity draw (φ) and a higher input efficiency thanks to the complementarity between imported intermediate goods and imported capital goods (γ_h). Since the demand is elastic, these lower prices imply that more productive firms using foreign-technology embodied in imported capital goods have also larger revenues and profits relative to those firms producing only with domestic capital goods (consistent with empirical fact 2).

Firms' decisions

The decision to exit or stay and produce

Firms have to pay a sunk entry cost f_e to enter the market before they know what their productivity level will be. Entrants then derive their productivity φ from common distribution density $g(\varphi)$, with support $[0, \infty)$ and cumulative distribution $G(\varphi)$. After observing its productivity draw, firms decide whether to stay and produce or to exit the market. Since there is a fixed production cost f, only those firms with enough profits to afford this cost can produce. The profits of the marginal firm that decides to stay and produce with low-technology are equal to zero: $\pi_l\left(\varphi_l^*\right) = 0$. The value φ_l^* is the survival productivity cutoff to produce with low-technology. This cutoff is determined by the following condition:

$$\pi_l\left(\varphi_l^*\right) = \frac{r_l\left(\varphi_l^*\right)}{\sigma} - f = \frac{A}{\sigma} c_l^{1-\sigma} \varphi_l^{*\sigma-1} - f = 0 \tag{5}$$

Equation (5) implies that the survival productivity cutoff to produce with low-technology is determined by $\varphi_l^{*\sigma-1} = f\, c_l^{\sigma-1} \frac{\sigma}{A}$. All firms that have a productivity draw lower than the survival cutoff are not able to pay the fixed production cost, they make losses and exit the market ($\varphi < \varphi_l^*$). Firms with a productivity draw greater than the survival cutoff stay in the market and produce ($\varphi > \varphi_l^*$).

The decision to adopt high-technology

If a firm decides to stay in the market once it has received its productivity draw, it may also decide to upgrade its technology by importing capital goods to reduce its marginal costs on the basis of its profitability. Technology choice is endogenously determined by the initial productivity draw. Firms with a more favorable productivity draw have a higher potential payoff from adopting the high-technology that is biased towards foreign inputs, and hence are more likely to find incurring the fixed technology cost worthwhile. Thus, firms that will upgrade technology are the most productive ones whose increase in revenues due to the adoption of high-technology enables them to pay the fixed technology cost to import capital goods. Technology adoption allows firms to increase their profitability through the complementarity channel between imported intermediate goods and imported capital goods in the production process.[17] The indifference condition for the marginal firm to acquire the new and more advanced foreign technology is given by $\pi_h(\varphi_h^*) = \pi_l(\varphi_h^*)$:

$$\frac{r_h(\varphi_h^*) - r_l(\varphi_h^*)}{\sigma} = f_h \tag{6}$$

The high-technology productivity cutoff φ_h^* is the minimum productivity level for the marginal firm that is able to adopt the high-technology and import capital goods. Equation (6) implies that $\varphi_h^{*\sigma-1} = \frac{f_h}{c_h^{1-\sigma}-c_l^{1-\sigma}}\frac{\sigma}{A}$. By combining equation (5) with (6), we obtain φ_h^* as an implicit function of φ_l^*:

$$\varphi_h^* = \varphi_l^* \left(\frac{f_h}{f}\right)^{\frac{1}{\sigma-1}} \left(\left(\frac{c_h}{c_l}\right)^{1-\sigma} - 1\right)^{\frac{1}{1-\sigma}} \tag{7}$$

Where the relative unit costs $\frac{c_h}{c_l}$ is a function of input and capital goods tariffs and the complementarity parameter between imported inputs and capital goods determined in equation (4). The sorting of firms by technology status depends on the relationship between fixed costs of production, of technology adoption and variable costs of importing intermediate inputs and capital goods. If fixed costs of adopting the high-technology are lower than fixed production costs all firms will use the high-technology. The parameter condition that ensures that $\varphi_h^* > \varphi_l^*$ is given by $f_h > f\left(\left(\frac{c_h}{c_l}\right)^{1-\sigma} - 1\right)$.

[17]Firms' technology adoption decision takes place after they discover their productivity draw. There is no other uncertainty or additional time discounting apart from the probability of exit (δ). Thus firms are indifferent between paying the one time investment cost F_h or paying the amortized per period portion of this cost in every period $f_h = \delta F_h$.

We are interested in determining how changes in input tariffs affect firms' decision to upgrade technology depending on their productivity levels. This question can be answered by investigating the impact of input-tariff changes on the high-technology productivity cutoff φ_h^*. Equation (7) shows that input tariffs affect the high-technology productivity cutoff through a direct effect captured by the relative unit costs of high-technology vis-a-vis low-technology and through an indirect effect captured by the impact of input tariffs on the survival productivity cutoff φ_l^*. Hence, to determine the high-technology productivity cutoff, we need to solve first for the equilibrium level of the survival productivity cutoff. This is done in the next section.

Industry equilibrium

Two conditions determined the equilibrium value of φ_l^*: the free entry condition (FE) and the zero cutoff profit condition (ZCP).[18] The FE condition represents a relationship between the average profits and the low-technology productivity cutoff level, where the average profits are an increasing function of the cutoff. In equilibrium, where entry is unrestricted, the net value of entry is equal to zero. Once firms pay the sunk entry costs, entrants then draw their productivity from a known Pareto distribution function $g(\varphi) = k\frac{\varphi_{\min}^k}{(\varphi)^{k+1}}$ with $\varphi_{\min} > 0$ the lower bound of the support of the productivity distribution and a shape parameter k. The Pareto cumulative distribution function is $G(\varphi) = 1 - \left(\frac{\varphi_{\min}}{\varphi}\right)^k$.[19]

$$\widetilde{\pi} = \frac{\delta f_e}{1 - G(\varphi_l^*)} = \left(\frac{\varphi_l^*}{\varphi_{\min}}\right)^k \delta f_e \qquad \text{(FE)} \tag{8}$$

Under the ZCP condition, average profits are a decreasing function of the cutoff.

$$\widetilde{\pi} = \rho_l \pi_l(\widetilde{\varphi_l}) + \rho_h \pi_h(\widetilde{\varphi_h}) \qquad \text{(ZCP)} \tag{9}$$

[18] All aggregate variables are defined in the Appendix.

[19] Assuming that productivity draws are Pareto distributed implies that firm size and variable profits are also Pareto distributed with a shape parameter $k/(\sigma - 1)$. The condition for average variable profits to be finite is that $k > \sigma - 1$. Axtell (2001) provides empirical evidence that the Pareto distribution is a good approximation of firm size distribution.

Where $\widetilde{\varphi_l}$ and $\widetilde{\varphi_h}$ correspond to the average productivity levels of firms producing with low- and high-technology, which depend on the productivity cutoff levels. $\rho_h = \frac{1-G(\varphi_h^*)}{1-G(\varphi_l^*)} = \left(\frac{\varphi_h^*}{\varphi_l^*}\right)^{-k}$ and $\rho_l = 1 - \rho_h$ represent the ex-ante probability of using high- and low-technology.

Combining the FE (equation (8)) and ZCP conditions (equation (9)), we can solve the equilibrium survival productivity cutoff. Derivations are detailed in the Appendix:

$$\varphi_l^{*k} = \frac{\sigma - 1}{k - (\sigma - 1)} \left[\frac{f \; + \left[\left(\frac{c_h}{c_l} \right)^{1-\sigma} - 1 \right]^{\frac{k}{\sigma-1}} \left(\frac{f_h}{f} \right)^{\frac{-k}{\sigma-1}} f_h}{\delta f_e} \right] \varphi_{\min}^k \tag{10}$$

where $k > \sigma - 1$ and the relative unit costs $\frac{c_h}{c_l}$ is a function of input tariffs τ_m, capital goods tariffs τ_k and the complementarity parameter γ_h determined in equation (4). In this model, the equilibrium productivity cutoff φ_l^* is a function of the input tariffs, the fixed production and high-technology costs and the complementarity technology parameter.

IV. INPUT-TRADE LIBERALIZATION AND TECHNOLOGY UPGRADING

Theoretical mechanisms

This simple model yields two main predictions related to the determinants of the probability of importing capital goods. The probability of adopting high-technology embodied in imported capital goods is determined by the relationship between the two productivity cutoffs defined in equation (7): $\rho_h = (\varphi_h^*/\varphi_l^*)^{-k}$. This equation shows that the probability of upgrading technology is a function of fixed production costs, fixed costs of high-technology, input and capital goods tariffs and the complementarity parameter. Input tariff cuts increase the likelihood of firms to upgrade high-technology.

Proposition 1: *The probability of adopting high-technology by importing capital goods ρ_h is a decreasing function of input tariff: $\partial\rho_h/\partial\tau_m < 0$.*

Using equation (7), we can express this probability as a function of the relative unit cost of high-technology that depends on input tariffs: $\rho_h = (f_h/f)^{\frac{-k}{\sigma-1}} \left((c_h/c_l)^{1-\sigma} - 1\right)^{\frac{-k}{1-\sigma}}$. From equation (4), we know that $\partial\frac{c_h}{c_l}/\partial\tau_m > 0$ since $0 < \alpha < 1$ and $\gamma_h > 1$, thereby, $\partial\rho_h/\partial\tau_m < 0$, since $\sigma > 1$.[20]

This model also predicts a heterogeneous effect of input-trade liberalization on firms' technology choice. The assumptions of firm heterogeneity and fixed costs of high-technology adoption imply that those firms that will be able to benefit from input-trade liberalization are the most productive firms using low-technology before input-tariff cuts. Using equation (7) and (10) to determine the high-technology productivity cutoff, we know that this cutoff decreases with input-tariff reductions. Input-trade liberalization induces the highest-productivity firms producing with low-technology to switch to high-technology.

Proposition 2: *The high-technology productivity cutoff φ_h^* is an increasing function of input tariffs: $\partial\varphi_h^*/\partial\tau_m > 0$*

Proof. *See Appendix.*

We focus on two testable predictions derived from propositions 1 and 2 which are in line with the empirical facts 5 presented in the previous section. These testable implications are presented in the next section. Input tariff reductions also induce a selection effect of most productive firms in this model. The least productive firms producing with low-technology intensive in domestic inputs will lose competitiveness and market shares relative to high-technology firms due to input-trade liberalization. Indeed, input tariff reductions imply an increase in the relative costs of domestic inputs vis-a-vis foreign intermediate goods. This is shown formally in the Appendix. Unfortunately, the Indian dataset that we exploit in the empirical analysis is not suitable to test this prediction since we cannot identify entry and exit of firms

[20] The model also predicts that the probability of importing capital goods is a decreasing function of capital goods tariffs. In the empirical analysis presented in the following sections we take into account the direct role of capital goods tariffs.

since firms are under no legal obligation to report to the data collecting agency, the Prowess data do not allow us to identify entry and exit of firms.

Testable implications

In the empirical analysis, we focus on firms' technological decision to import capital equipment goods in India. The simple model presented in the previous section yields two testable implications on the relationship between changes in input tariffs and firms' decision to upgrade technology embodied in foreign capital goods.

Input tariff cuts imply a reduction of the relative costs of foreign inputs vis-a-vis domestic ones. Taking into account that the high-technology embodied in imported capital goods is biased towards imported inputs and the substitutability between intermediate goods, input-trade liberalization in this framework enhances the cost-advantage of high-technology firms. Thereby, input tariff cuts reduce the relative unit costs of using high-technology, increasing profits of high-technology firms relative to low-technology firms creating incentives to upgrade technology embodied in imported capital goods. Proposition 1 shows that input tariff reductions increase the likelihood of firms to adopt the high-foreign technology by importing capital goods.

Testable implication 1: *Input-trade liberalization has a positive effect on firms' decision to import capital goods.*

Which are the firms that decide to upgrade foreign-technology after input-trade liberalization?

The effect of input tariff reductions on firms' technology choice is heterogeneous across firms depending on their initial productivity level φ. Proposition 2 shows that the high-technology productivity cutoff φ_h^* decreases with input tariff reductions. Figure 1 illustrates the impact of input-trade liberalization on firms' technology choice for firms with different productivity levels. Input tariff cuts reduce the high-technology productivity cutoff, allowing the most productive firms producing with low-domestic technology before input-trade liberalization to upgrade their technology embodied in imported capital goods ($\varphi_h^{*'} < \varphi < \varphi_h^*$). These firms will experience an increase in the expected profits of high-technology, due to input tariff reductions, that allows them to cover the fixed technology adoption costs.

Testable implication 2: *The effect of input-trade liberalization is heterogeneous across firms. Firms that will benefit from input tariff cuts to upgrade foreign technology embodied in imported capital goods are firms in the middle range of the productivity distribution.*

In the following sections, we test these empirical implications using the episode of India's trade liberalization at the beginning of the 1990s.

V. EMPIRICAL ANALYSIS

Data

The Indian firm-level dataset is compiled from the Prowess database by the Centre for Monitoring the Indian Economy (CMIE).[21] This database contains information from the income statements and balance sheets of listed companies comprising more than 70 percent of the economic activity in the organized industrial sector of India. Collectively, the companies covered in Prowess account for 75 percent of all corporate taxes collected by the Government of India. The database is thus representative of large and medium-sized Indian firms. As previously mentioned this dataset was already used in several studies on the performance of Indian firms.[22]

The dataset covers the period 1989-1997 and the information varies by year. It provides quantitative information on sales, capital stock, income from financial and non financial sources, consumption of raw

[21] The CMIE is an independent economic center of India that provides services of primary data collection through analytics and forecasting. Further information can be found at http://www.cmie.com/.

[22] See Topalova and Khandelwal (2011), Topalova (2004), Goldberg et al. (2010), Goldberg et al. (2009), Alfaro and Chari (2009), DeLoecker et al. (2016).

material and energy, compensation to employees (wage-bill) and ownership group.[23] This dataset allows us to estimate firm total factor productivity (TFP) using the Levinsohn and Petrin (2003) methodology. The Prowess database provides detailed information on imports by category of goods: finished goods, intermediate goods and capital goods. In our main empirical specification, we use imports of capital goods (machinery and equipment) to measure foreign technology. Although we are not able to test directly for the impact of imported capital goods depending on the country of origin since the Prowess dataset does not include the origin country of imported goods (e.g developed vs. developing countries), one realistic assumption for the case of a developing country like India is that most imports of capital goods are sourced from more advanced economies and thus, they are a good proxy of a modern and high-technology. Looking at imports of capital goods at HS6 product level of India by country of origin reveals that about 70% of their imports came from developed countries in the period 1989-1997.[24]

Input-trade liberalization might also allow firms to access to high-quality inputs. Using detailed firm-product level data for Colombia, Kugler and Verhoogen (2009) compare the price of domestic and imported inputs and provides evidence that higher-quality inputs may be relatively more available internationally. Due to data constraints, we are not able to look at the effects of input-liberalization on quality up-grading. The Prowess database does not provide any information on quantities to compute unit values as a proxy of quality of intermediate goods. Despite that we can not observe the quality of intermediate goods, for imported capital goods we can infer that they are more advanced or of a higher quality relative to domestic capital equipment goods produced in India since most of the imports of capital goods come from developed economies.

Our sample contains information for around 3,744 firms in organized industrial activities from manufacturing sector for the period 1990-1997. Since we lagged control variables, our estimating sample starts in 1990 and the total number of observations firm-year pairs is 14,425. In order to keep a con-

[23]Variables are deflated with industry-specific wholesale price indices from India's national accounts statistics.

[24]We used the BACI database provided by the CEPII as well as the Broad Economic Categories (BEC) classification of HS6 products by intermediates, capital goods and consumption goods.

stant sample throughout the paper and to establish the stability of the point estimates, we keep firms that report information on all the firm and industry level control variables. Although our panel of firms is unbalanced, there is no statistical difference in the average firm characteristics between the initial year and the final year of our sample.

Input-tariff data

To identify the impact of input-trade liberalization on firms' foreign technology choice, we use input tariffs at the 3-digit-NIC industry level. Tariffs data is provided by WITS (World Bank) and corresponds to India's effectively applied most favorite nation (MFN) import tariffs with respect to the Rest of The World at the industry level ISIC (rev 2).[25] In order to identify the effect of input tariff changes on firms' decision to import capital goods, we construct different tariffs measures for capital goods and for variable intermediate goods. In this sense, we depart from previous studies on input-trade liberalization to consider both variable inputs and capital goods in the construction of input tariffs.

This methodology allows us to disentangle the indirect effects of tariffs on intermediate goods on firms' decision to import capital goods from the direct effects of tariffs on capital goods. For each 3-digit industry, s, we generate a capital goods tariff as the weighted average of tariffs on the capital goods used in the production of final goods of that 3-digit industry, where the weights reflect the share of capital goods of the final goods industry on total expenditures in capital goods using India's input-output matrix in 1993. We rely on fixed input weights and a pre-sample year input-output matrix to avoid possible endogeneity concerns between variations in input weights and industry and firm performance. Using a disaggregated input-output matrix, 14 from a total of 52 industries are classified as capital goods.[26]

[25] We use correspondence tables to convert tariffs into ISIC rev 3.1. that match almost perfectly with NIC 3-digit classification. This dataset is available at http://wits.worldbank.org/wits/.

[26] Capital goods industries are tractors and agriculture machinery, industrial machinery, industrial machinery (others), office computing machines, other non-electrical machinery, electrical industrial machinery, communication equipments, other electrical machinery, electronic equipments, ships and boats, rail equipments, motor vehicles motor cycles and other transport equipments.

Similarly, for each industry, s, we generate an input tariff as the weighted average of tariffs on all the other intermediate goods (excluding capital goods) used in the production of final goods of that industry, where the weights reflect the input industry's share of the output industry's total expenditures in other inputs using India's input-output matrix in 1993.

We compute input (capital goods) tariffs as $\tau_{st} = \sum_z \alpha_{zs}\tau_{zt}$, where $\alpha_{\mathbf{zs}}$ is the value share of input (capital) z in the production of output in the 3-digit industry s. Take for example an industry that uses three different intermediate goods in the production of a final good. Suppose that the intermediate goods face a tariff of 5, 10 and 15 per cent, and value shares of 0.10, 0.30 and 0.60, respectively. Using this methodology, the input tariff for this industry is 12.5 percent (5 $\times$0.10 + 10$\times$0.30 + 15$\times$0.60).

Trade liberalization in India

The main feature of trade reform in India was the substantial trade-integration process experienced in the 1990s. In this section, we describe India's trade liberalization process and the trade-policy instruments that were applied.

India's trade policy during the 1970s and 1980s was characterized by the license raj. This trade system was grounded on trade protection policies with an emphasis on import substitution. It was very restrictive, with high levels of nominal tariffs and import licenses in almost all sectors.

Unilateral trade-reform plan was launched in the early 1990s as a consequence of the debt crisis and as a part of an IMF program. Trade liberalization was at the core of structural reforms launched during the 'Eighth Five-Year Plan' period from 1992 to 1997. Under this plan, gradual tariff cuts were applied in all sectors at the same time that non-tariff barriers and licenses were removed. As Topalova and Khandelwal (2011) emphasize after 1997 tariff changes were not as uniform and the issue of potential endogeneity of trade protection might be present in the period of the 'Ninth Five-Year Plan'. For this reason, we restrict our analysis to the 1989-1997 period.

During this period India also becomes a member of the WTO (World Trade Organization) in 1995. One of the commitments of India when decides to join WTO is to continue the process of trade liberalization started at the early 1990s. From 1995, India starts implementing Uruguay Round commitments that were completed in 2005 (see India's Trade Policy Review by WTO in 2007).

Average input tariffs have declined by 27 percentage points during the period, while capital goods tariffs were only slightly reduced by 10 percentage points. This descriptive evidence suggests that changes in variable inputs and capital goods tariffs were heterogeneous. They were also weakly correlated.[27] There is also significant variation in movements in input tariffs by industry over the 1989-1997 period. At the 2-digit industry level, industries that experienced the greatest input tariff cuts are cloth, plastic, machinery, wood and paper (Figure A1 in the online appendix). At the more disaggregated 3-digit industry level there is even more variation in input tariffs.

Exogenous input tariffs variations

One of the challenges in the investigation of the relationship between input-tariff reductions and firm decisions to upgrade foreign technology embodied in imported capital goods is potential reverse causality between tariff changes and firms' import choices which would bias our estimates.[28] In this case, changes in input tariffs could reflect some omitted industry characteristics.

One way of addressing this issue is to test whether tariff changes are exogenous to initial industry and firm characteristics. Similar to previous works analyzing the effects of trade liberalization on different firm performance measures, Topalova and Khandelwal (2011), we regress first changes in input tariffs on a number of industry characteristics computed as the size-weighted average of firms' characteristics in the initial year of our sample. Table A2 in the online appendix shows the coefficients on the change

[27] The correlation between average output tariffs and input tariffs is 0.45 and between output and capital goods tariffs is 0.01.

[28] Karacaovali (2011) shows theoretically and empirically how productivity at the industry level could affect tariff rates at the sectoral level.

in input tariffs and capital goods tariffs (1989-1997) on industry level regressions of initial industry characteristics (sales, capital stock, wage-bill, imports of intermediates and capital goods) on these tariff changes. The estimates confirm that input tariff changes between 1989 and 1997 were uncorrelated with initial industry-level outcomes in 1989. As such, it seems unlikely that firms producing in industries with greater input-tariff cuts were able to lobby for these lower tariffs.

Next, following the analysis of Goldberg et al. (2010) we provide additional evidence that input tariff changes between 1989 and 1997 were uncorrelated with initial firm performance measures in 1989 that we are considering in this analysis. Table A3 in the online appendix shows estimates from regressing firm characteristics in 1989 such as the importer status, the share of imported capital goods over total sales, the logarithm of capital stock and firm TFP on the variation in input tariffs and capital goods tariffs across industries between 1989 and 1997. Had the government targeted specific firms/industries during trade liberalization, we would expect tariff changes to be correlated with initial firm performance. However, the correlation is insignificant.

This evidence suggests that the government did not take into account pre-reform trends in firms' imports of capital goods and other performance measures when deciding to reduce tariff during trade reform at the beginning of the 1990s.

Input tariff cuts and firm decision to import capital goods

Using specific tariffs on inputs (different from capital goods tariffs), we investigate the relationship between the availability of imported intermediate goods and firms' decision to upgrade foreign technology embodied in imported capital goods. To test the first implication of the model, we estimate the probability that firm i imports capital goods in year t using the following linear probability model:

$$Importer(k)_{ist} = \gamma_1 Input\tau_{s,t\text{-}1} + \gamma_2 Z_{s,t\text{-}1} + \gamma_3 X_{i,t\text{-}1} + \mu_i + \upsilon_t + \epsilon_{ist}(I)$$

Here $Importer(k)_{ist}$ is a dummy variable for firm *i* producing in industry s having positive imports of capital goods in year t. $Input\ \tau_{s,\,t\text{-}1}$ represents the input tariffs of industry *s* in year $t-1$. We have already shown that we rely on exogenous changes in tariffs that are not correlated with initial firm or industry characteristics. Moreover, we use lagged tariffs values to ensure that contemporaneous firms' decisions cannot affect past values of tariffs. $Z_{s,t\text{-}1}$ is a set of industry level control variables and $X_{i,t\text{-}1}$ is a set of firm level observable characteristics varying over time. All specifications include firm fixed effects, μ_i, that take into account unobservable and time-invariant firm characteristics and year fixed effects that control for macroeconomic shocks affecting all firms and industries in the same way, υ_t. Since tariffs vary at the 3-digit industry level over time, the errors are corrected for clustering across 3-digit industry level.

As discussed above, input-tariff changes are not correlated with either initial firm characteristics or industry characteristics during the period 1989-1997. To deal with additional concerns of reverse causality and omitted variables, we introduce different control variables at the industry level which may affect firms' import decisions of capital goods and could reflect the effects of input-tariff changes. The γ_1 coefficient on input tariffs might then simply be picking up the effects of variations of tariffs on capital goods. The simple model presented in the previous section also predicts that the probability of importing capital goods is a decreasing function of capital goods tariffs. Hence, we first include India's import tariffs on capital goods to capture the direct effects of variations in tariffs affecting capital equipement products on firms' decision to import those capital goods. Second, all specifications also include tariffs on final goods. This variable captures foreign competition pressures. Finally, we also include a Herfindahl index at the sectoral level to control for domestic competition. Note that in order to keep the theoretical framework simple and rationalize the effects of input-tariff on foreign technology adoption, the model abstracts from these competition channels. They should be, however, included in the empirical estimation to avoid omitted variable concerns.

Next, we also explicitly take into account changes in observable firm characteristics that could affect firms' import patterns. Using the same dataset, Bas and Berthou (2012) have found evidence on a positive correlation between firms' decision to import capital goods and firms' capital intensity. We therefore expect that non-importing Indian firms which experienced significant growth in their capital intensity during the period under analysis were more likely to import capital goods. $X_{i,t\text{-}1}$ is a set of firm-level controls such as firms' capital intensity and the age of the firm. The Prowess dataset contains the year of creation of the firm that allows computing the age of the firm.[29]

Table 3 shows the estimation results for equation (I) using a within-firm estimator. These results show the impact of lower input tariffs on the decision to import capital goods. In column (1) the coefficient on the input tariffs is negative and significant at the 1% confidence level, indicating that the drop in input tariffs between 1989 and 1997 increased the probability of importing capital goods. The estimated input tariff coefficient is robust to the inclusion of MFN tariffs for final goods set India (column 2). We also introduce tariffs on capital goods to be sure that the input tariffs are not just capturing the effect of changes in direct tariffs of imported capital equipment products (column 2). Not surprisingly, reductions in tariffs on capital goods enhance the probability of upgrading foreign technology embodied in imported capital goods. More interesting, the inclusion of capital goods tariffs does not pick up the indirect effect of reductions of tariffs on intermediate inputs. We next include additional industry and firm-level variables to control for industry and firm observable characteristics that vary over time and which could be related to input tariffs. The coefficient of interest on input tariff is robust and stable when we control for domestic competition measured by the Herfindahl index (column (3)), the age of the firm and firm capital intensity (column (4)). The coefficient on input-tariff changes remains negative, significant and stable, however. It is very similar in size to the estimations with only industry-level controls shown in column (1).

If the availability of foreign intermediate goods induces firms to start importing capital goods, we would expect the effect of lower input-tariffs to be greater for firms that actually import intermediate

[29]The Prowess dataset does not report consistent information on number of employees.

inputs. Columns (5) and (6) carry out this test. First, we inlcude a dummy variable equal to one if the firm imports intermediate goods. Firms sourcing inputs from abroad are more likely to also import capital goods (column 5) confirming the previous descriptive evidence on technological complementarity between imported inputs and foreign technology. [30] Next, we introduce an interaction between input tariff and importer of intermediate goods status (column (6)).

Comparing the coefficients of tariffs on capital goods with those on intermediate goods (column (6)) reveals that the indirect effect of input tariffs cuts on the probability of upgrading capital goods is of a similar magnitude to the direct effect of reducing capital goods tariffs. The estimated coefficient of variable input tariff cuts implies that a 10 percentage point fall in input tariffs leads to 1.5% to almost 1.7% increase in the probability of importing capital goods for the average firm and for those actually importing intermediate goods. Between 1989 and 1997, input tariffs declined on average by 27 percentage points, with an associated implied increase in the probability of importing capital goods of about 4.6 for the average firm importing intermediate goods. These findings suggest that the additional gains from input-trade liberalization thanks to the complementarity channel of imported inputs and capital goods are non negligible.

Table 3 about here

The heterogeneous effects of input tariff cuts

The simple model presented in Section 3 shows that input-trade liberalization affects firms differently according to their initial productivity. Most firms with a high-productivity level might already import capital goods before input tariff cuts, while the least productive firms might not be able to afford the fixed

[30]As previously mentioned, unfortunately the Indian firm level dataset does not allow us to test the quality upgrading channel of imported inputs or to distinguish the country of origin of imports of intermediate goods in order to provide a better assessment of the complementarity mechanism.

cost of importing capital goods despite input tariff changes. The model predicts that firms using low-technology before the reform that have a productivity level close to the high-technology productivity cutoff will benefit from input tariff reductions to face the sunk costs of importing capital goods. We explore in this section whether the impact of input-tariff changes on firms' decision to import capital goods depends on previous firm productivity.

To investigate the heterogeneous effect of input-trade liberalization on firms' decision to import capital goods, we introduce interactions between input-tariff changes and quantiles of firms' TFP in the initial year of the sample. We rely on firm initial TFP to avoid potential endogeneity issues between firm performance and imports of capital goods. Firms are divided up into three initial TFP quantiles with the first one representing the least productive firms (those firms with an initial TFP lower than the 33rd percentile), the second group covers middle range initial productivity firms (between the 33rd and 66th percentile) and the last group represents the high initial productivity firms (with an initial TFP higher than the 66th percentile).[31] We then interact input-tariff with the firms' initial TFP quantiles. We estimate the following linear probability model for the decision to import capital goods:

$$Importer(k)_{ist} = \sum_{\rho=1}^{4} \chi^{\rho}(Input\tau_{s,t-1} \times Q_{is}^{\rho}) + \gamma_2 Z_{s,t\text{-}1} + \gamma_3 X_{i,t\text{-}1} + \mu_i + \upsilon_t + \epsilon_{ist} (II)$$

Here $Importer(k)_{ist}$ is a dummy variable for firm i in 3-digit industry s having positive imports of capital goods in year t. Firms are classified into three groups of initial TFP by ρ: Q_{is}^{1} is a dummy variable for firm i belonging to the group of the least productive firms and so on. $Input\tau_{s,t-1} \times Q_{is}^{\rho}$ are the interaction terms between the three groups of firms' TFP and input tariff. We include the same industry (output tariffs, capital goods tariffs and Herfindahl index) and firm-level (age, capital intensity and the intermediate goods importer status) controls as in the previous estimations. The dummy variables for each group of firm initial TFP are excluded from the estimation since they are collinear with the firm

[31] Firm TFP is estimated using the Levinsohn and Petrin (2003) methodology.

fixed effects.

The estimation results for equation (II) are presented in Table 4. Note that in this specification we restrict the sample to firms that are present in the initial year and so the number of observations is reduced. Column (1) reports as a benchmark the baseline estimates on the sample of firms that are present in the initial year. Columns (2) to (4) introduce the interaction terms between input tariffs and firms' initial TFP quantiles. The impact of input tariffs on the probability of importing capital goods is only significant for firms in the middle range of the initial productivity distribution. This result is consistent with the predictions of our model. Since firms faced fixed sunk costs of importing capital goods, only those firms that were not importing capital goods before the input-tariff reform and that are productive enough to pay the importing fixed costs are able to import capital goods thanks to the reduction of input tariffs. The estimated coefficient implies that the 27 percentage point fall in input tariffs during the period leads to almost 10% increase in the probability of importing capital goods for firms in the middle range of the initial productivity distribution.

Table 4 about here

VI. ALTERNATIVE EXPLANATIONS

There are other potential explanations for the incentives of Indian firms to upgrade foreign technology embodied in imported capital goods over the 1989-1997 period, with the input-trade liberalization being one of them. In this section, we discuss and examine three alternative explanations: (i) other reforms that took place in India during this period, (ii) learning effects, (iii) foreign demand shocks (export-channel) and (iv) firms' financial health. First we describe our strategies to take into account these alternative factors in the estimations. We then present evidence showing that our previous findings remain stable when including these factors suggesting that the input tariff cuts channel is an important factor determining firms' foreign technology upgrading decision.

Other reforms in India

During the 1990s India has experienced structural reforms in several areas of the economy. In order to test if the coefficient on input tariffs is picking up the effects of other reforms that took place in India, we carry out alternative sensitivity tests.

Table A4 in the online appendix presents the results. The benchmark estimation presented in column (5) of table 3 is reported in column (1). Next, we include in column (2) industry-year fixed effects to take into account all unobservable characteristics varying over time that could affect industries. In this case only the interaction term between input tariff and the importer of intermediate goods status variable is included. The coefficient of the interaction term is negative and significant, and the magnitude is slightly smaller relative to the one found in the baseline specification reported in column (1).[32]

Since other reforms like labor market regulations were introduced at the beginning of the 1990s at the State level, we introduce region-year fixed effects to control for unobservable characteristics affecting the 21-Indian states in columns (3) and (4). As can be seen the coefficient of interest on input tariffs and on the interaction term between input tariffs and the initial quartiles of firm TFP remain robust and stable to the inclusion of region-year fixed effects. The point estimates of input tariffs remain robust relative to the ones presented in the baseline specifications in Table 3 and 4.

Overall, these results confirm that our previous findings do not suffer from omitted variables bias related to other policy-reforms that took place in India.

Learning effects

Learning by importing channel could also explain the relationship between input trade liberalization and foreign technology upgrading in imports of capital goods. Firms that import intermediate inputs

[32]Note that in the specification in which we include industry-year and firm fixed effects in column (2), the effect of input tariff and initial quantiles of firm TFP will be completely subsumed by the fixed effects.

might learn about sourcing countries and providers and it is easier for them to start importing capital goods with the new information acquired than firms that face foreign sellers for the first time. Note that testing directly this mechanism requieres further information on the country of origin of imports that is not available for the Indian dataset.

We present here a test for this channel that relies on past import experience on intermediate goods as a proxy of learning effects. The previous specification is extended to include an interaction term between intermediate good tariff with the number of prior years in which the firm imported intermediate goods. Results are presented in columns (5) and (6) of Table A4 in the online appendix. The coefficient measuring past import experience is positive but not significant and the interaction term with input tariffs is negative but also not significant. Nevertheless, this alternative channel is not picking up the effects of our main variable of interest: input tariffs cuts have still significant effect on the probability of importing capital goods on average and mainly firms in the middle range of the productivity distribution benefit from input-tariffs liberalization to upgrade foreign technology in imported capital goods.[33]

Foreign demand shocks

In the simple theoretical framework presented in Section 3, we emphasize the imported input channel as the main mechanism through which trade liberalization affects firms' decision to upgrade foreign technology. For the sake of simplicity we did not take into account the export side of the story and the effects of trade liberalization through variations in trade variable costs affecting final goods that are already well-documented in the theoretical literature (Yeaple, 2005; Bustos, 2011).

Expansion of export opportunities due to foreign demand shocks might also increase the incentives for firms' to upgrade foreign technology embodied in imported capital goods. Moreover, importing intermediate inputs might lead to higher exports as documented in the empirical literature (Feng et al.,

[33] We thank an anonymous referee for suggesting this test.

2016; Bas, 2012; Bas and Strauss-Kahn, 2015). Higher export profits would allow to overcome the fixed cost of importing capital goods. If input tariff changes are positively correlated with export performance or with variations in output tariffs set by India's trading partners, our previous empirical findings might be just picking up the effects of foreign demand shocks.

The industry-year fixed effects included in the estimations of the previous section already address this issue since they capture all unobservable shocks at the industry level varying over time. In this section, we provide additional evidence that foreign demand shocks at the sectoral level captured by export tariffs are not picking up our results. We control for this alternative explanation by including in the previous specifications the average effectively applied tariff at the 3-digit NIC industry level set by the rest of the world to India (export tariff) during the 1989-1997 period from WITS dataset (World Bank). Columns (1) to (3) of Table A5 in the online appendix report the results. The effect of export tariff is negative but not significant. The coefficient of interest on the input tariffs remains robust and stable in all specifications when we take into account the role of foreign demand. This finding suggests that the supply side mechanism emphasized in this paper is also an important channel through which trade liberalization affects technology upgrading.

Firms' financial health

In a previous work, we have shown that firms' financial health is an important determinant of firms' decision to import capital goods in India (Bas and Berthou, 2012). We investigate whether the previous findings are not driven by an omitted variable bias related to firms' financial health. The previous estimations are extended to include lagged values of the leverage ratio (borrowings over total assets) of the firm. Columns (4) to (6) of Table A5 in the online appendix present the findings. As in our previous study, we find that firms' financial health is an important determinant of firms' decision to upgrade foreign technology. Nevertheless, our coefficient of interest on input tariffs is not affected by the inclusion of firms' financial variables.

VII. OTHER ROBUSTNESS TESTS

The decision to start importing capital goods

We explore the robustness of our baseline specification when we restrict our sample to firms that have not imported capital goods in the previous years. The estimates from linear probability estimations of equation (I) and (II) with firm and year fixed effects for the restricted sample of firms that have not imported capital goods in the previous year or two years are reported in Table 5. In these cases, the coefficients on input tariff are higher compared to the baseline specification. We should keep in mind that this could be due to the reduction of the sample size to half from 14,425 to around 9,200 or 5,500 observations.

Table 5 about here

The role of firm ownership

In this section, we investigate if firms' ownership is driving our previous results. Previous studies on multinational firms show that foreign firms in developing countries tend to use more advanced technologies and be more productive relative to domestic firms (Javorcik, 2004). In general, the fact that foreign companies are more efficient and use more advanced technology could potentially explain our results. Foreign affiliates might benefit more from input tariff changes to upgrade foreign technology embodied in imported capital goods since they have connections with foreign headquarters located abroad. In order to address this issue, we carry out two different tests.

First, we test for the possibility that foreign spillovers are driving our findings: if multinational companies benefit the most from input-trade liberalization there could also be foreign technology transfer to domestic firms. We include in the previous specification a variable measuring the number of foreign affiliates in the region (Indian state) and industry where the firm is producing and an interaction term between this variable and input tariffs. Columns (1) and (2) of Table 6 present the results. The presence of multinational affiliates increases the probability that Indian firms upgrade their technology and the interaction term suggests that input tariffs cuts have a greater effect on firms located in states and industries that have experienced an increase in the number of foreign affiliates (column 1). Once we control for this potential alternative explanation, our coefficient of interest on input tariffs alone is lower in magnitude but still significant and negative. Moreover, the heterogeneous effect of input tariff cuts depending on firms' initial TFP is robust and stable (column 2).

Second, we exclude from our sample multinational firms in columns (3) and (4) of Table 6. Our coefficients of interest on input tariff (column (3)) and on the interaction term between input tariff and the initial firm TFP quantile (column (4)) remain robust when we restrict the sample to domestic firms, suggesting that input-trade liberalization matters for non-multinational firms.

Moreover, previous works using the same firm-level dataset have emphasized the role of state-owned firms relative to private companies in India (Topalova, 2004; Alfaro and Chari, 2009). One could argue that state-owned companies might have a greater lobby power to induce the government to reduce tariff on those goods that they use as intermediate ones in the production of final goods. In order to address this issue, we restrict the sample to private firms in columns (5) and (6). The point estimates of input tariff (column (5)) and the interaction term between input tariff and the initial firm TFP quantile (column (6)) remain robust and stable for the sample of private firms.

Table 6 about here

VIII. ADDITIONAL GAINS FROM INPUT-TRADE LIBERALIZATION

The previous results show that lower tariffs on intermediate inputs increases the probability of importing capital goods, in addition to the direct effect of lowering tariffs on capital goods. Those findings suggest that the potential gains from trade liberalization might be larger than in previous studies when one takes into account the additional gains from input tariff cuts on the decision to import capital goods (the indirect channel). This section discusses the additional gains at the firm level of input-trade liberalization thanks to the complementarity channel between variable foreign inputs and capital goods.

The intensive margin of imports of capital goods

If imports of intermediate goods are complementary with imports of capital goods, we expect that input tariff reductions will also enhance larger volumes of imports of capital goods. One concern that arises in the estimation of the determinants of the intensive margin of imports of capital goods is that this variable is observed only over some interval of its support. An OLS estimation of the logarithm of imports of capital goods will exclude the zero import values leading to sample-selection bias and inconsistent parameter estimates as the censored sample is not representative of the entire sample of Indian firms.

To address this issue we present Tobit estimates with imports of capital goods shares on the left-hand side explicitly taking censoring into account by considering the zero values as a left-censored.[34] Tobit models with individual fixed effects have an incidental parameters problem, and are generally biased (Greene 2003). We thus report results from both pooled Tobit, without unobserved effects, and random effects Tobit.[35] Table 7 presents the results. Columns (1) and (2) show the marginal effects at the sample

[34]The predicted values from Tobit estimations account for the lower limit of the censored data. We should keep in mind that Tobit estimation relies on the assumption of homoskedastic normally-distributed errors for consistency.

[35]In the random effects Tobit, firm unobserved heterogeneity is assumed to be part of the composite error. Random-effects Tobits are unbiased if firm characteristics are exogenous (uncorrelated with the regressors). Honore (1992) has developed a semiparametric method dealing with this issue which captures unobserved time-invariant individual heterogeneity. He proposes a trimmed least squares estimator of censored regression models. Nevertheless, this semiparametric estimator for fixed-effect Tobits is not suitable here due to the relatively small sample size.

mean from pooled Tobit estimation of tariffs on imports of capital goods shares and columns (3) and (4) report the results from random-effects Tobits. The coefficient of interest on input tariffs is negative and significant in all specifications implying that input-trade liberalization increases the share of imports of capital goods.

Table 7 about here

Input-trade liberalization, firm profitability, sales and electricity

Next, we explore the relationship between input-tariff cuts and other firm outcomes such as firms' profits, sales and electricity consumption. Previous literature has already shown that India's trade liberalization yields to larger gains from new imported varieties of intermediate goods (Goldberg et al. (2010)).

The simple theoretical model presented in Section 3 emphasizes that input-tariff reductions allow firms to increase their profits and sales to afford the high-technology. We thus estimate equation (I) with the logarithm of firms' profits and sales as dependent variables and we include an interaction term between input tariffs and a dummy variable equal to one when the firm imports capital goods. Since the estimation includes firm and year fixed effects, the coefficient on the interaction term captures the effect of input tariff cuts on firms' profits and sales for firms that start importing capital goods. Table 8 presents the results. Columns (1) and (3) show that firms that upgrade their foreign technology embodied in imports of capital goods increase their sales and profits as predicted by the model. Input-tariff reductions lead to greater sales and profits for firms that start importing capital goods of about 4% (columns (2) and (4)).

Finally, we test the assumption that Indian firms are upgrading their technology by importing capital goods. More advanced technologies are more likely to be reliant on electricity. Thereby, we expect that

Indian firms increase their consumption of electricity as a result of input tariff cuts and importing capital goods. Columns (5) and (6) of Table 8 show that this was indeed the case.[36]

IX. CONCLUDING REMARKS

The main contribution of this paper to the literature on the micro-economic effects of input-trade liberalization on firm performance is to investigate the efficiency gains from input tariff cuts on firms' decision to source capital goods from abroad.

We motivate our empirical analysis with a simple theoretical model of heterogeneous firms that explains the channels through which changes on tariff on intermediate goods might affect firms' decision to upgrade foreign technology in imported capital goods. Assuming that imported intermediate inputs and foreign-technology are complementary and fixed costs of technology upgrading, the model predicts a positive effect of reductions of tariff on intermediate goods on firms' choice to adopt a foreign-technology. The impact of input-trade liberalization is heterogeneous across firms depending on their initial productivity level.

Using Indian firm-level data and the trade liberalization episode at the early 1990s, we test the main implications of the model. Our findings demonstrate that the probability of importing capital goods is higher for firms producing in industries that have experienced greater cuts on tariff on intermediate goods. Looking at the heterogeneous effect of input-trade liberalization, we find that only those firms in the middle range of the productivity distribution have benefited from input tariff cuts as predicted by the model. These empirical findings are robust to alternative specifications that control for imported capital goods tariffs, other reforms, and industry and firm characteristics.

Table 8 about here

[36]We thank an anonymous referee for suggesting this test.

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A Appendix

Aggregation

The low-technology average productivity level $\widetilde{\varphi}_l$ and the ex-ante weighted average productivity level of high-foreign-technology firms $\widetilde{\varphi_h}$ is given by:

$$\widetilde{\varphi}_l \equiv \frac{1}{G(\varphi_h^*) - G(\varphi_l^*)} \int_{\varphi_l^*}^{\varphi_h^*} (\varphi)^{\sigma-1} g(\varphi) d\varphi = \varphi_l^* \upsilon^{\frac{1}{\sigma-1}} \left[\frac{1-\xi^{-k+\phi-1}}{1-\xi^{-k}} \right]^{\frac{1}{\sigma-1}} \qquad \text{if } \varphi_l^* \leq \varphi < \varphi_h^*$$

$$\widetilde{\varphi_h} \equiv \frac{1}{1-G(\varphi_h^*)} \int_{\varphi_h^*}^{\infty} (\varphi)^{\sigma-1} g(\varphi) d\varphi = \varphi_h^* \upsilon^{\frac{1}{\sigma-1}} \qquad \text{if } \varphi \geq \varphi_h^*$$

where $\upsilon = \frac{k}{k-(\sigma-1)}$ and $\xi = \left(\frac{f_h}{f}\right)^{\frac{1}{\sigma-1}} \left[\left(\frac{c_h}{c_l}\right)^{1-\sigma} - 1 \right]^{\frac{1}{1-\sigma}}$.

The ex-post average productivity of high-foreign-technology firms takes into account the increase in the firms' efficiency due to the acquisition of the more advanced technology complementary with imported intermediate inputs. The adoption of the high technology allows these firms to reduce their unit costs and raise their market shares by this term $\left(\frac{c_h}{c_l}\right)^{1-\sigma}$. Notice that average revenues of high-technology firms can be expressed as $r_h(\widetilde{\varphi_h}) = r_l(\widetilde{\varphi_h}) \left(\frac{c_h}{c_l}\right)^{1-\sigma}$. Therefore, the weighted average productivity index of the industry $\widetilde{\varphi_T}$ represents the market shares of all types of firms: $\widetilde{\varphi_T}^{\sigma-1} = \frac{1}{M} \left[M_l \left(\widetilde{\varphi}_l\right)^{\sigma-1} + M_h \left(\frac{c_h}{c_l}\right)^{1-\sigma} \left(\widetilde{\varphi_h}\right)^{\sigma-1} \right]$.

The number of firms producing with low technology $M_l = \rho_l M$ and those producing with high technology $M_h = \rho_h M$ are determined by the total number of firms M and the probabilities of using low and high technology. $\rho_h = \frac{1-G(\varphi_h^*)}{1-G(\varphi_l^*)} = \left(\varphi_h^*/\varphi_l^*\right)^{-k}$ and $\rho_l = 1 - \rho_h$. The low- and high-technology average productivity levels and the aggregate productivity index define all the aggregate variables.

The price index of the industry is determined by:

$$P^{1-\sigma} = M_l \int_{\varphi_l^*}^{\varphi_h^*} (p_l)^{1-\sigma} \mu_l(\varphi) d\varphi + M_h \int_{\varphi_h^*}^{\infty} (p_h)^{1-\sigma} \mu_h(\varphi) d\varphi \; =$$

$$\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} c_l^{1-\sigma} \left[M_l \left(\widetilde{\varphi_l}\right)^{\sigma-1} + M_h \left(\frac{c_h}{c_l}\right)^{1-\sigma} \left(\widetilde{\varphi_h}\right)^{\sigma-1} \right]$$

Using the aggregate productivity $\widetilde{\varphi_T}$, the price index can be expressed as $P^{1-\sigma} = M\left(\frac{\sigma}{\sigma-1}\frac{c_l}{\widetilde{\varphi_T}}\right)^{1-\sigma} = Mp\left(\widetilde{\varphi_T}\right)^{\sigma-1}$.

Proof. of the equilibrium survival productivity cutoff

FE (8) and ZCP (9) conditions jointly determine the equilibrium cutoff level (φ_l^*). In order to obtain this cutoff, we use the technology productivity cutoff, the average productivity for low-and high-technology ($\widetilde{\varphi_l}, \widetilde{\varphi_h}$) firms and the probability of using low- and high-technology (ρ_l, ρ_h). The equilibrium cutoff level (φ_l^*) is given by:

$$\frac{\varphi_l^{*k}}{\varphi_{\min}^k} \delta f_e = \frac{1}{M}\left[\frac{1}{\sigma}\left[M_l \int_{\varphi^*}^{\varphi_h^*} r_l(\varphi)\mu_l(\varphi) d\varphi + M_h \int_{\varphi_h^*}^{\infty} r_h(\varphi)\mu_h(\varphi) d\varphi\right] - Mf - M_h f_h\right]$$

Solving for low and high technology revenues and using $M_l = \rho_l M, M_h = \rho_h M, r_l = Ac_l^{1-\sigma}\varphi_i^{\sigma-1}, r_h = Ac_h^{1-\sigma}\varphi_i^{\sigma-1}$ and using equation (5), to determine A, so as to express average profits as a function of the productivity cutoff, yields:

$$\frac{\varphi_l^{*k}}{\varphi_{\min}^k} \delta f_e = \left[\rho_l \left(\frac{\widetilde{\varphi_l}}{\varphi_l^*}\right)^{\sigma-1} + \rho_h \left(\frac{c_l}{c_h}\right)^{\sigma-1} \left(\frac{\widetilde{\varphi_h}}{\varphi_l^*}\right)^{\sigma-1} - 1\right] f - \rho_h f_h$$

By substituting the average productivity for low-and high-technology $\widetilde{\varphi_l}, \widetilde{\varphi_h}$ and using the high-productivity cutoff defined in equation (7), yields:

$$\varphi_l^{*k} = \frac{\sigma - 1}{k - (\sigma - 1)} \left[\frac{f \ + \left[\left(\frac{c_h}{c_l}\right)^{1-\sigma} - 1 \right]^{\frac{k}{\sigma-1}} \left(\frac{f_h}{f}\right)^{\frac{-k}{\sigma-1}} f_h}{\delta f_e} \right] \varphi_{\min}^k \qquad \text{(A.1.)}$$

This cutoff, φ_l^*, then determines the high-technology productivity cutoff level φ_h^* defined in equation (7).

Proof. of proposition 2.

This high-technology productivity cutoff is an increasing function of input tariff (τ_m). Keeping in mind that $\frac{c_h}{c_l}$ is an increasing function of τ_m[37], we take the partial derivative of the productivity technological cutoff (φ_h^*) determind in Equation (7) with respect to τ_m:

$$\frac{\partial \varphi_h^*}{\partial \tau_m} = \frac{\varphi_h^*}{\varphi_l^*} \left[\frac{\partial \varphi_l^*}{\partial \tau_m} + \frac{\partial \frac{c_h}{c_l}}{\partial \tau_m} \frac{\varphi_l^*}{\left[\left(\frac{c_h}{c_l}\right)^{1-\sigma} - 1 \right] \left(\frac{c_h}{c_l}\right)^{\sigma}} \right] \qquad \text{(A.2.)}$$

Next, we partially differentiate equation (A.1) φ_l^* with respect to τ_m, to obtain $\frac{\partial \varphi_l^*}{\partial \tau_m}$:

[37] Partially differentiating equation (3) with respect to the input tariffs (τ_m), we find that $\partial \frac{c_h}{c_l} / \partial \tau_m > 0$ since $0 < \alpha < 1$ and $\gamma_h > 1$.

$$\frac{\partial \varphi_l^*}{\partial \tau_m} = (-1)\left(\varphi_l^{*k}\right)^{\frac{1}{k}-1} \frac{\partial \frac{c_h}{c_l}}{\partial \tau_m} \frac{\left[\left(\frac{c_h}{c_l}\right)^{1-\sigma} - 1\right]^{\frac{k}{\sigma-1}-1} \left(\frac{f_h}{f}\right)^{\frac{-k}{\sigma-1}} f_h}{\delta f_e} \left(\frac{c_h}{c_l}\right)^{-\sigma} \varphi_{\min}^k \left(\frac{\sigma-1}{k-(\sigma-1)}\right) < 0 \tag{A.3.}$$

Since $\frac{\partial \frac{c_h}{c_l}}{\partial \tau_m} > 0$, $\left(\frac{c_h}{c_l}\right)^{1-\sigma} > 1$ and $\frac{\sigma-1}{k-(\sigma-1)} > 0$, yields to $\frac{\partial \varphi_l^*}{\partial \tau_m} < 0$.

Plugging equation (A.3) into equation (A.2), a sufficient condition for $\frac{\partial \varphi_h^*}{\partial \tau_m} > 0$ is:

$$\varphi_l^{*k} > \frac{\sigma-1}{k-(\sigma-1)} \left[\left[\left(\frac{c_h}{c_l}\right)^{1-\sigma} - 1\right]^{\frac{k}{\sigma-1}} \left(\frac{f_h}{f}\right)^{\frac{-k}{\sigma-1}} \frac{f_h}{\delta f_e}\right] \varphi_{\min}^k \tag{A.4.}$$

To prove that this condition holds, we plug in the equation (A.4) the survival productivity cutoff φ_l^* as determined in equation (10) and we obtain:

$$f > 0$$

Figure 1: Heterogeneous effect of input-trade liberalization on firms' technology choice

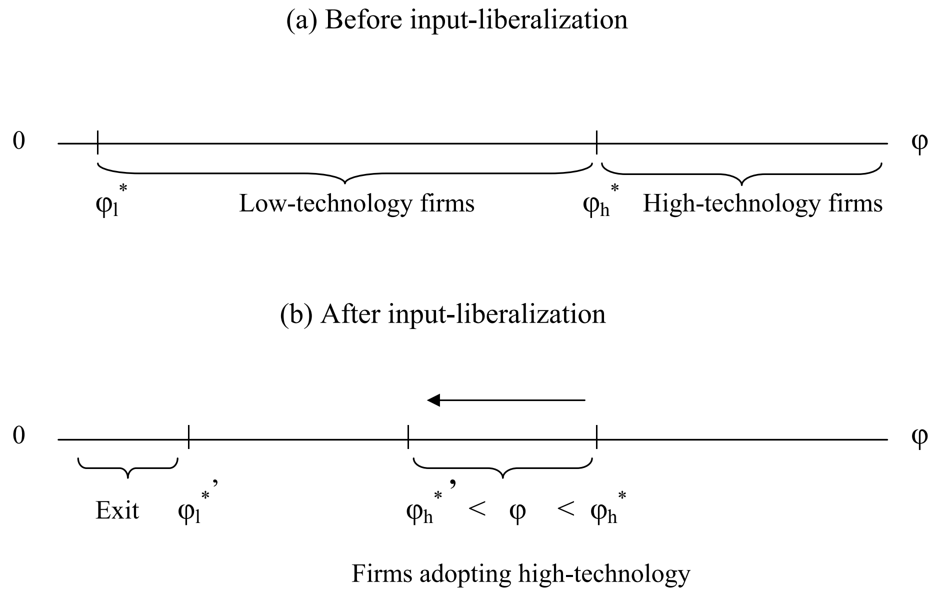

Table 1: Importers vs. non-importers of capital goods: Importer of capital goods premia

The dependent variable is described in each column					
	(1)	(2)	(3)	(4)	(5)
	Sales	Capital	Wage-bill	Profits	Imported inputs share
Importer of capital goods	1.356***	1.517***	1.350***	1.558***	0.085***
	(0.043)	(0.045)	(0.049)	(0.051)	(0.014)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	14,680	14,647	14,680	11,945	14,680
R-squared	0.224	0.283	0.202	0.214	0.005

Notes: The dependent variable is described in the head of each column, all of those variables are expressed in logarithm terms except by the share of imported inputs. The table shows regressions of each firm performance measure on a dummy variable equal to one if the firm imports capital goods in year t and zero otherwise. All regressions include industry and year fixed effects. Heteroskedasticity-robust standards errors clustered at the firm level are reported in parentheses.

Table 2: Complementarity between imports of capital goods and intermediate inputs

Dependent variable: Importer of capital goods status				
	(1)	(2)	(3)	(4)
Imported input share	0.032***	0.058***	0.046***	0.047***
	(0.004)	(0.004)	(0.005)	(0.005)
Firm size		Yes		Yes
Industry 3 digit fixed effects	Yes	Yes		
Firm fixed effects			Yes	Yes
Year Fixed effects	Yes	Yes	Yes	Yes
Observations	14,680	14,680	14,680	14,680
R-squared	0.262	0.326	0.092	0.294

Notes: The dependent variable is a dummy for firm i having positive imports of capital goods in year t. The imported input share is the ratio of imported inputs over total inputs. Firm size is measured by the logarithm of wage-bill and it is included in columns (2) and (4). Heteroskedasticity-robust standards errors clustered at the firm level are reported in parentheses. ***, **, and *indicate significance at the 1, 5 and 10 percent levels respectively.

Table 3: Input-tariff liberalization and firms' decision to import capital goods

Dependent variable: dummy equal to one if the firm i imports capital goods in t.						
	(1)	(2)	(3)	(4)	(5)	(6)
Input tariff(s)(t-1)	-0.166***	-0.149**	-0.152**	-0.152**	-0.151**	-0.012
	(0.056)	(0.060)	(0.060)	(0.060)	(0.069)	(0.078)
Input tariff(s)(t-1)$\times$ imported inputs$>$0						-0.170**
						(0.066)
Capital goods tariff(s)(t-1)		-0.165**	-0.168**	-0.170**	-0.168*	-0.173**
		(0.073)	(0.073)	(0.073)	(0.086)	(0.083)
Output tariff(s)(t-1)		-0.057	-0.057	-0.053	-0.026	-0.030
		(0.047)	(0.047)	(0.047)	(0.041)	(0.040)
Herfindhal index(s)(t-1)			0.044	0.045	0.022	0.024
			(0.049)	(0.049)	(0.059)	(0.059)
Age(t-1)				-0.004	-0.016	-0.011
				(0.028)	(0.033)	(0.034)
Capital intensity(t-1)				0.013**	0.014**	0.015*
				(0.006)	(0.007)	(0.007)
Imported inputs$>$0					0.333***	0.405***
					(0.028)	(0.041)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,680	14,680	14,680	14,680	14,680	14,680
R-squared	0.036	0.036	0.036	0.036	0.093	0.094

Notes: The dependent variable is a dummy for firm i having positive imports of capital goods in year t. Output tariff(s)(t-1) are MFN applied tariffs from WITS-WB dataset at the 3 digit industry level and input and capital goods tariffs are constructed separately using these output tariffs and India 1993 input-output matrix. Importer inputs is a dummy equal to one if the firm imports intermediate goods. Herfindahl index measures the concentration of sales of the industry. Capital intensity is measured by capital stock over sales of the firm. The Prowess dataset reports the year of creation of the firm that allows to construct the age of the firm. Heteroskedasticity-robust standards errors are reported in parentheses. Errors are corrected for clustering at the 3-digit industry level. ***, **, and *indicate significance at the 1, 5 and 10 percent levels respectively.

Table 4: The heterogeneous effects of input-tariff liberalization on firms' decision to import capital goods

Dependent variable: dummy equal to one if the firm i imports capital goods in t.				
	(1)	(2)	(3)	(4)
Input tariff(s)(t-1)	-0.201*			
	(0.102)			
Input tariff(s)(t-1)× Low initial TFP		-0.111	-0.145	-0.149
		(0.111)	(0.105)	(0.104)
Input tariff(s)(t-1)× Medium initial TFP		-0.315***	-0.345***	-0.346***
		(0.110)	(0.104)	(0.103)
Input tariff(s)(t-1)× High initial TFP		-0.043	-0.067	-0.058
		(0.164)	(0.146)	(0.151)
Capital goods tariff(s)(t-1)	-0.181*	-0.150	-0.170*	-0.176*
	(0.095)	(0.108)	(0.096)	(0.095)
Output tariff(s)(t-1)	-0.040	-0.055	-0.041	-0.033
	(0.047)	(0.052)	(0.048)	(0.051)
Imported inputs>0	0.344***		0.344***	0.344***
	(0.029)		(0.029)	(0.029)
Age(t-1)	0.022			0.031
	(0.057)			(0.061)
Capital intensity(t-1)	0.018			0.019
	(0.012)			(0.012)
Herfindhal index(s)(t-1)	0.004			0.013
	(0.067)			(0.069)
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	7,861	7,861	7,861	7,861
R-squared	0.087	0.038	0.088	0.088

Notes: The dependent variable is a dummy for firm *i* having positive imports of capital goods in year *t*. Input tariff(s)(t-1) are interacted with quartiles of firm TFP in the initial year of the sample. Firm TFP is estimated using the Levinsohn and Petrin (2003) methodology. All control variables are defined in table 3. Industry control variables (output tariffs, capital goods tariffs and the Herfindahl index) are included in all specifications. Heteroskedasticity-robust standards errors are reported in parentheses. Errors are corrected for clustering at the 3-digit industry level.***, **, and *indicate significance at the 1, 5 and 10 percent levels respectively.

Table 5: The decision to start importing capital goods

Dependent variable: dummy equal to one if the firm i imports capital goods in t.				
	(1)	(2)	(3)	(4)
	Non importer in the last year		Non importer in the last two years	
Input tariff(s)(t-1)	-0.210**		-0.249*	
	(0.099)		(0.133)	
Output tariff(s)(t-1)	0.069	0.088	0.083	0.094
	(0.046)	(0.065)	(0.060)	(0.077)
Capital goods tariff(s)(t-1)	-0.248**	-0.234*	-0.376**	-0.443**
	(0.118)	(0.124)	(0.172)	(0.201)
Input tariff(s)(t-1) × Low initial TFP		-0.262		-0.289
		(0.153)		(0.182)
Input tariff(s)(t-1) × Medium initial TFP		-0.304**		-0.393**
		(0.127)		(0.186)
Input tariff(s)(t-1) × High initial TFP		-0.082		-0.269
		(0.155)		(0.187)
Herfindahl index(s)(t-1)	Yes	Yes	Yes	Yes
Firm level controls	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yess
Year fixed effects	Yes	Yes	Yes	Yes
Observations	9,228	4,245	5,439	2,758
R-squared	0.029	0.031	0.056	0.066

Notes: The dependent variable is a dummy for firm i having positive imports of capital goods in year t. All control variables are defined in table 3. Heteroskedasticity-robust standards errors are reported in parentheses. Errors are corrected for clustering at the 3-digit industry level. ***, **, and *indicate significance at the 1, 5 and 10 percent levels respectively.

Table 6: The role of firm ownership

Dependent variable: dummy equal to one if the firm i imports capital goods in t.						
	(1)	(2)	(3)	(4)	(5)	(6)
	MNF spillovers		Without MNF firms		Private firms	
Input tariff(s)(t-1) x MNF(r,s,t)	-0.086*	-0.072				
	(0.044)	(0.058)				
MNF(r,s,t)	0.057*	0.070				
	(0.034)	(0.044)				
Input tariff(s)(t-1)	-0.119*		-0.185**		-0.150**	
	(0.070)		(0.081)		(0.067)	
Input tariff(s)(t-1) × Low initial TFP		-0.130		-0.205		-0.163
		(0.107)		(0.119)		(0.105)
Input tariff(s)(t-1) × Middle initial TFP		-0.323***		-0.416***		-0.340***
		(0.106)		(0.115)		(0.103)
Input tariff(s)(t-1) × High initial TFP		-0.025		-0.089		-0.039
		(0.158)		(0.161)		(0.143)
Capital goods and output tariff(s)(t-1)	Yes	Yes	Yes	Yes	Yes	Yes
Herfindahl index(s)(t-1)	Yes	Yes	Yes	Yes	Yes	Yes
Industry level controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm level controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,680	7,861	13,300	6,817	14,247	7,593
R-squared	0.094	0.089	0.097	0.093	0.096	0.091

Notes: The dependent variable is a dummy for firm i having positive imports of capital goods in year t. MNF(r,s,t) is the logarithm of the number of foreign affiliates located in the same region (r) and industry (s). All other control variables are defined in table 3. Heteroskedasticity-robust standards errors are reported in parentheses. Errors are corrected for clustering at the 3-digit industry level.***, **, and *indicate significance at the 1, 5 and 10 percent levels respectively.

Table 7: Input-trade liberalization and the intensive margin of imports of capital goods

Dependent variable: the share of imported capital goods over total imports of the firm i in t.				
	(1)	(2)	(3)	(4)
	Pooled Tobit		Random effects Tobit	
Input tariff(s)(t-1)	-0.378***	-0.362***	-0.218***	-0.225***
	(0.066)	(0.066)	(0.064)	(0.064)
Capital goods and output tariff(s)(t-1)	Yes	Yes	Yes	Yes
Random effects			Yes	Yes
Industry fixed effects			Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	10,800	10,800	10,800	10,800
log likelihood	-5533	-5412	-4457	-4436
Sigma u	0.352	0.348	0.267	0.261
Sigma e			0.264	0.264

Notes: The dependent variable is the share of imported capital goods over total sales of the firm i in year t. All specifications include capital goods and output tariffs and the Herfindahl index. Columns (2) and (4) also include firm-level controls. All control variables are defined in table 3. Heteroskedasticity-robust standards errors are reported in parentheses. Errors are corrected for clustering at the 3-digit industry level. ***, **, and *indicate significance at the 1, 5 and 10 percent levels respectively.

Table 8: Additional gains from input-trade liberalization

Dependent variable: logarithm of profits or sales or electricity of firm i in t.						
	(1)	(2)	(3)	(4)	(5)	(6)
	Profits		Sales		Electricity consumption	
Importer capital goods	0.128***	0.308***	0.098***	0.268***	0.091***	0.213***
	(0.025)	(0.057)	(0.010)	(0.029)	(0.011)	(0.027)
Input tariff(s)(t-1) × Importer capital goods		-0.427***		-0.409***		-0.297***
		(0.123)		(0.055)		(0.057)
Input tariff(s)(t-1)		-0.200		0.169		-0.194*
		(0.308)		(0.113)		(0.106)
Capital goods and output tariff(s)(t-1)	Yes	Yes	Yes	Yes	Yes	Yes
Herfindahl index(s)(t-1)	Yes	Yes	Yes	Yes	Yes	Yes
Industry level controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm level controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11,945	11,945	14,680	14,680	14,662	14,662
R-squared	0.178	0.182	0.604	0.607	0.708	0.709

Notes: The dependent variable is the logarithm of firms' profits (columns 1 and 2) or sales (columns 3 and 4) in year t. All control variables are defined in table 3. Heteroskedasticity-robust standards errors are reported in parentheses. Errors are corrected for clustering at the 3-digit industry level.***, **, and *indicate significance at the 1, 5 and 10 percent levels respectively.