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Import Competition and Firm Productivity: Evidence from German Manufacturing*

Abstract

This study analyses empirically the effects of import competition on firm productivity (TFPQ) using administrative firm-level panel data from German manufacturing. We find that only import competition from high-income countries is associated with positive incentives for firms to invest in productivity improvement, whereas import competition from middle- and low-income countries is not. To rationalise these findings, we further look at the characteristics of imports from the two types of countries and the effects on R&D, employment and sales. We provide evidence that imports from high-income countries are relatively capital-intensive and technologically more sophisticated goods, at which German firms tend to be relatively good. Costly investment in productivity appears feasible reaction to such type of competition and we find no evidence for downscaling. Imports from middle- and low-wage countries are relatively labour-intensive and technologically less sophisticated goods, at which German firms tend to generally be at disadvantage. In this case, there are no incentives to invest in innovation and productivity and firms tend to decline in sales and employment.

Keywords: productivity, multi-product firms, import competition

JEL classification: D22, D24, F10, F14, F60, F61, L25

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1. Introduction

It is a widespread opinion that competition forces firms to increase efficiency and productivity. Competition threatens firms' rents and even their existence. To escape competition, firms take costly actions to improve their efficiency and productivity (Aghion et al. 2004, 2005, 2009 and for an overview Holmes and Schmitz 2010). The alleged productivity gains of intensified competition have also been an important argument for the openness of a country to international trade. However, notwithstanding abundant, previous research has mainly analyzed the effects of international trade in general and/or does not explicitly distinguish between between- and within-firm productivity effects of import competition (Shu and Steinwender 2019). And while the empirical evidence about how import competition affects domestic firms and shapes their incentives to increase productivity is rather limited, the discussion in academic and in policy circles is intense (cf., Shu and Steinwender 2019).

We analyze empirically the effect of import competition on (within-)firm productivity. We distinguish between import competition from high-income countries and from middle- and low-income countries, since differences in the comparative (dis-)advantages of domestic firms relative to imports from different countries might result in differential incentives to invest in productivity in reaction to competition. To better understand the productivity effects of import competition, we also analyze its effects on firms' sales, employment, and R&D investment.

We use high-quality and very comprehensive, administrative firm-level panel data from German manufacturing for the period 2000-2014. Particularly the availability of information on final products' quantities and (factory-gate) prices allows us to take firm heterogeneity into account and to more precisely assess the impact of import competition on firm productivity. One the one hand, using product portfolio information, we assess the firm-specific strength of import competition. This allows us (i) to take into account that competition takes place on output markets rather than within (broadly defined) industries and (ii) to separate the effect of import competition from further productivity enhancing channels such as the access to cheaper or better inputs, or embodied technology imports if, for instance, competition is measured at the industry-level (Young 1991; Kasahara and Rodrigue 2008; Lileeva and Trefler 2010; Goldberg et al. 2010; Halpern et al. 2015; Ahn and Duval 2017).[1] Moreover, we back out a quasi-quantity-based productivity measure (TFPQ) that is, differently from revenue-based productivity measures (i.e., TFPR), not confounded by firm-specific price setting factors (e.g., market power), which might lead to an underestimation of the true effects of import competition (Eslava et al. 2004; Foster et al. 2008; Smeets and Warzynski 2013; De Loecker 2011). To draw causal inference, we apply an IV-2SLS strategy and instrument the German imports from the different types of countries with the imports of third countries from the same set of trade partners, which reflect the genuine competitiveness of the latter and are (arguably) exogenous (i.e., unrelated to the performance of domestic firms) (Autor et al. 2013).

Overall, we find a positive effect of import competition on the productivity of domestic firms. On average, an increase in import competition by one percentage point is associated with an increase in firm TFPQ by ca. 0.2 percent. However, the productivity effects appear to stem from import competition from other industrialized, high-income countries, while import competition from less developed, low- to middle-income countries has no effect on productivity. According to the estimates, a one percentage point increase in import competition from high-income countries is associated with an increase in firm productivity by 1.1 percentage points. Moreover, we find that import competition from middle- and low-income countries is associated with a decline in firms' sales, employment and R&D investment, whereas the results for the effects import competition from developed high-income countries indicate no drop in sales, employment or R&D investment.

Our interpretation of the findings is the following. We show that imports from high-income countries threaten mainly relatively capital- and R&D-intensive domestic products, while imports from middle- and low-income countries threaten mainly relatively labor-intensive products. This corresponds to previous research that, in line with the relative comparative advantages framework in international economics, documents that compared to high-income countries, middle- and low-income countries export rather labor-intensive goods that use rather standard technologies and are characterized by lower unit costs of production and lower quality (cf., Schott 2004; Hummels and Klenow 2005; Khandelwal 2010; Amiti and Khandelwal 2013; Cali et al. 2016). These differences in the characteristics of the imports imply different types of competition that domestic firms are

[1] The imports of an industry might be final output for some firms in that industry but also inputs to other firms in the same industry.

facing and different strategies and/or 'abilities' to cope with it. German manufacturing firms have higher incentives to invest in innovation and productivity to cope with competition from other industrialized, high-income countries because they are more 'competent' at the same types of comparably capital-intensive, technologically sophisticated, complex, and (vertically) differentiable goods and products. The increase in productivity is accompanied by or even due to an increase in R&D, and we do not observe drop in sales and employment (i.e., downscaling or exit from certain markets). On the opposite, not only is investment in knowledge and technologies to escape competition relatively costly in the case of comparably labor-intensive and less R&D-intensive goods that use 'standard' technologies and simple labor, but high-wage-facing German manufacturing firms are at an relative disadvantage when competing with firms from developing, middle- and low-income countries with comparably more of simple and cheap labor. In this case, the incentives for domestic firms to invest in innovation and costly productivity are relatively low and to exit the particular market relatively high.

This paper adds to the vast literature on the effects of international trade liberalization in general. Recent research in international economics considers the heterogeneity of both domestic firms and foreign partners and that the effects of trade liberalization depend on the performance of domestic firms relative to their foreign opponents. For instance, in Melitz (2003) stiff competition and selection triggered by trade liberalization result in less productive firms declining and/or exiting the market and a reallocation of market shares to higher productivity firms. Bernard et al. (2003, 2007) show how this process of reallocation of resources and creative destruction can strengthen comparative advantages. However, in this literature the major mechanism behind aggregate productivity gains is the inter-firm dynamics. We add to that by focusing on rather intra-firm (or within-firm) productivity dynamics. In this regard, this paper relates also to more general frameworks, where an increase in productivity is a result of actions deliberately taken by firms to cope with competition (Aghion et al. 2004, 2005, 2009).

We also complement existing empirical research on different aspects of the impact of imports from low-wage countries, in particular from China, on industrialized economies. Our findings are in line with Bernard et al. (2006a), Mion and Zhu (2013) and Auer et al. (2013), who provide evidence that price pressure induced by low-wage countries competition results in a decline in employment and survival of firms in industrialized countries and a (within-industry) reallocation towards capital-intensive production, mostly because costs reduction potential (e.g., downward wage flexibility) in industrialized countries is not sufficient to offset the relative disadvantages. Our paper also relates to Autor et al. (2017) and Bloom et al. (2016) who look at the innovation effects of import competition from China. However, by not explicitly focusing on China, but rather analyzing imports from middle- and low-income countries and from high-income countries, our findings are far more general and help better understand the effects of import competition and international trade with multiple and heterogeneous trade partners and suggest a more differentiated picture.

Not least, our study complements empirical work on the effects of trade liberalization in general and the reduction of trade costs (e.g., industry-wide tariffs) in particular on firm performance (Pavcnik 2002; Trefler 2004; Bernard et al. 2006a, b; Amiti and Konings 2007; Topalova and Khandelwal 2011; De Loecker 2011). We add to this literature by specifically analyzing the role of import competition.

The remainder of the paper is structured as follows. Section two introduces the administrative data on manufacturing firms in Germany and outlines the measurement of both firm-specific strength of import competition and firm productivity. Section three describes our econometric strategy to assess the impact of import competition on firm productivity. Section four presents the results of the econometric analysis of the effect of competition on productivity. Section five concludes.

2. Data and measuring import competition and productivity

2.1 Firm data

We use publically available administrative yearly panel data on German manufacturing firms with at least 20 employees (*Amtliche Firmendaten in Deutschland*, *AFiD* thereafter) for the period 2000-2014, maintained by the German Federal Statistical Office. *AFiD* contain information on firms' production inputs and output as well as a variety of further firm characteristics.[2] In principle, *AFiD* comprise of the universe of firms with at least 20 employees. Yet, selected variables are collected only for a representative subsample of about 40% of the targeted population. This concerns information on intermediate inputs expenditures and employment by full time equivalents, which are necessary to estimate firm total factor productivity. Thus, we use this subsample in the further analysis. As this subsample is stratified by industry and size-class, variables observable for all firms in *AFiD*, we construct and use (inverse probability) weights to make the results representative for the whole population in *AFiD*.

Notably, *AFiD* provide detailed information on quantities and factory gate prices for the distinct final products of each firm at the nine-digit-level of the *PRODCOM* classification. This information allows us to take firm heterogeneity explicitly into account, which is a twofold advantage. It allows us to assess the firm-specific strength import competition (cf., section 2.2). This accounts, compared to industry-wide measures, for the fact that competition takes place on output markets rather than within industries and also allows us to disentangle the effect of final product competition from further influences, if for instance the imports of a certain industry are final output for some firms in that industry and inputs for other firms in the same industry. Final products' quantities and prices information also allows us to arrive at quasi-quantity-based productivity measure (TFPQ) that is not confounded by firm-specific prices (cf., section 2.3). Overall, this allows us to more precisely assess the impact of import competition on productivity.

2.2 Measuring import competition

We measure the firm-specific strength of import competition by combining *AFiD* information on firms' final products portfolios and information on German imports from the United Nations *Comtrade* database that contains information on the value and quantities of distinct products traded between any two countries (UN Statistics Division 2009). In particular, we calculate firm-level import competition as the share of imports in each firm's total market:

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[2] We use the following *AFiD* modules: module products (*AFiD-Module Produkte*), module plants (*AFiD-Panel Industriebetriebe*), module firms (*AFiD-Panel Industrieunternehmen*).

(1) $$IC_{it}^{n} = \sum_g \left[\left(\frac{R_{igt}}{\sum_g R_{igt}} \right) \left(\frac{M_{gt}^{n}}{M_{gt}^{World} + \sum_i R_{igt}} \right) \right] * 100,$$

where g, i, and t indicate the product, firm, and time dimension. R_{igt} and $\sum_g R_{igt}$ are a firm revenues with product g and firm total revenue, respectively. $\sum_i R_{igt}$ denotes the value of Germany's total production of product g (by firms with at least 20 employees). M_{gt}^{n} is the value of the total German imports of product g from a country(-group) n, where $n = (High, Low)$ indicates high-income countries or middle- and low income countries. In our case, the high-income country group consists of USA, Canada, Japan and South Korea. The middle- and low-income country group includes China, India, Russia, Brazil, South Africa, Argentina, Chile, Mexico, Malaysia, Turkey, Thailand, Tunisia, Bangladesh, Indonesia, Philippines, Vietnam and Pakistan (cf., section 3 for further details and discussion). M_{gt}^{World} is the value to total imports of product g.

As mentioned earlier, we distinguish between import competition from high-income countries and import competition from middle- and low-income countries to capture potential differences in their impact on domestic firms. Such differences could arise if there are differences in the types of goods and products imported from different countries (e.g., characteristics, production factors' and technology intensity), which imply differences in the type of competition they impose on domestic firms. Indeed, in line with the specialization and trade pattern predicted by the comparative advantage framework in international trade, the exports of middle- and low-income developing countries are typically found to be relatively labor-intensive, technologically less sophisticated, to have lower unit costs of production and to be of lower quality (Schott 2004; Hummels and Klenow 2005; Khandelwal 2010; Amiti and Khandelwal 2013; Cali et al. 2016).

Table 1: Import competition from high-income countries and from low-income countries

	Firms predominantly exposed to import competition from high-income countries (mean / median)	Firms predominantly exposed to import competition from low-/middle-income countries (mean / median)
IC^{High}	13.44 / 10.63	1.29 / 0.63
IC^{Low}	1.79 / 1.30	20.22 / 13.41
K/L (€ / fte)	123,185 / 83,251	92,076 / 68,846
R&D / L (€ / fte)	5,926 / 1,683	1,340 / 0
R&D / Sales (%)	3.05 / 1.06	0.76 / 0

Note: Firms are exposed predominantly to import competition from high-/low-income countries if competition from high-/low-income countries is at least three times larger than competition from low-/high-income countries. Import competition from high-income countries and from middle- and low-income countries is calculated according to equation (1) as the share of imports from a certain group of countries in the total market of each individual firm; unweighted mean / median, 2000-2014. The group of high-income countries (for IC^{High}) includes USA, Canada, Japan, and South Korea. The group of low-income countries (for IC^{Low}) includes China, India, Russia, Brazil, South Africa, Argentina, Chile, Mexico, Malaysia, Turkey, Thailand, Tunisia, Bangladesh, Indonesia, Philippines, Vietnam and Pakistan (cf., next Section 3 for discussion on country selection). Capital to labor ratio, *K/L*, is measured in € per employee (in full time equivalents, fte), unweighted mean / median, 2000-2014. *R&D / L* is R&D expenditures in € per employee (in full time equivalents, fte), unweighted mean / median, 2000-2014. *R&D / Sales* is R&D expenditures in € over total sales in € (in %), unweighted mean / median, 2000-2014.

Table 2 shows selected patterns in the measures for import competition from high-income countries and from low- to middle-income countries. Since we do not have explicit information about the factor and technology content of imports, we compare the capital-to-labor ratio and the R&D intensity of domestic firms that are predominantly exposed to imports from high-income countries and these domestic firms that are predominantly exposed to imports from low- and middle-income countries. Though not perfect, this allows us to learn about the content/nature of the imports from the two types of countries. In line with previous research mentioned in the paragraph above, also our findings indicate that imports from high-income countries are more capital- and R&D-intensive than imports from low-income countries. The capital-to-labor ratio of firms with products that face competition mainly from high-income countries is on average 34% higher (ca. 21% for the median firm) than that of firms whose products face competition mainly from low-income countries. The R&D expenditures per full time employee or as a share in the total sales of firms with products facing competition from mainly high-income countries are on average at least four times larger than these of firms, whose products face import competition mainly from low-income countries. Generally, import penetration from low-income countries is relatively high in rather basic and comparably labor-intensive sectors of the economy (e.g., clothing, fabricated metal products) as well as in sectors using comparably 'standard' technologies (e.g., household and consumer electronics). On the opposite, import penetration from high-income countries is relatively high in sectors that use advanced and high-end technologies for high-quality intermediate and capital goods (e.g., certain types of chemical products, mechanical engineering, electrical and optical equipment, medical and precision instruments), but also in the case of complex and R&D-intensive final products (e.g., pharma).

2.3 Assessing firm productivity

We assume that firms produce output with a Cobb-Douglas technology

(2) $$Q_{it} = L_{it}^{\beta^l} K_{it}^{\beta^k} M_{it}^{\beta^m} e^{\omega_{it}},$$

where Q_{it} denotes the total sales of firm i at time t and is deflated with an index for the price of the composite output of each individual firm, based on information on final products' quantities and prices in the data (cf., Appendix A). This is particularly helpful since (multiproduct) firms report different products in different units, but more importantly, allows us to interpret Q_{it} as quasi-physical output (cf., Eslava et al. 2004). Labor, L_{it}, is measured in full time equivalents. K_{it} and M_{it} are capital stock and total intermediates expenditures, deflated with the respective two-digit NACE rev. 1.1 deflators from the German Federal Statistical Office.[3] Firm total factor productivity, ω_{it}, is a Hicks-neutral shifter. Because Q_{it} can be interpreted as quasi-physical output, ω_{it}, can be interpreted as quasi-physical-based measure of TFP (i.e., TFPQ), which, compared to revenue-based TFP (TFPR), is not confounded by firm-specific factors that influence prices such as market power (Foster et al. 2008; Eslava et al. 2004). Taking logs of (2) yields the following empirical production function

(3) $$q_{it} = \beta^l l_{it} + \beta^k k_{it} + \beta^m m_{it} + \omega_{it} + \varepsilon_{it},$$

where smaller letters denote logs and ε_{it} enters as an i.i.d. disturbance.

[3] See Appendix B for the construction of the capital series.

However, we include the price for the composite output of the firm, π_{it}, in the production function (3) to account for unobserved price or 'quality' differences in the intermediate inputs, which might bias the estimates of TFPQ since we only observe the total expenditures for intermediate inputs and not their quantities and prices (Fox and Smeets 2011; De Loecker et al. 2016). We follow De Loecker et al. (2016) who argue that for a large class of models of consumer demand and imperfect competition, observed output prices can be used to proxy unobserved intermediate prices and qualities, since expensive and high-quality products typically require expensive and high-quality inputs. Hence, the production function becomes:

(4) $$q_{it} = \beta^l l_{it} + \beta^k k_{it} + \beta^m m_{it} + \gamma\pi_{it} + \omega_{it} + \varepsilon_{it}.$$

ω_{it} is, however, unobserved and some structure and assumptions need to be imposed in order to recover it from the data. We follow the control function approach by Olley and Pakes (1996) and Levinsohn and Petrin (2003). In particular, we assume that firms know their productivity, ω_{it}, and consider it when making decision on the amount of flexible inputs. This gives us the opportunity to use these flexible inputs to proxy productivity in (4). In line with Levinsohn and Petrin (2003), we use energy and raw materials (which are components of total intermediates), denoted by e_{it}, to proxy productivity. Capital and, because of relatively strong regulations in Germany, labor are assumed pre-determined at time t.[4] Inverting firm's demand function for inputs yields the proxy or control function for productivity[5]

(5) $$\omega_{it} = g_{it}(.) = g_{it}(k_{it}, l_{it}, e_{it}, \boldsymbol{z}_{it}),$$ [6]

where $\boldsymbol{z}_{it}$ is an additional set of variables to account for further factors that might affect firms' demand for e_{it} (De Loecker and Warzynski 2012; De Loecker et al. 2016). As noted by De Loecker and Warzynski (2012) and De Loecker et al. (2016), $\boldsymbol{z}_{it}$ should be specified as broadly as possible. We include the number of products, dummy variable for exporting,

[4] See OECD (2018) for employment protection in Germany.

[5] A necessary condition to invert the demand function for e_{it} is that e_{it} monotonically increases in ω_{it} (Levinsohn and Petrin 2003).

[6] We define $g_{it}(.)$ as a third order polynomial in k_{it}, l_{it} and e_{it}, while $\boldsymbol{z}_{it}$-variables enter linearly.

dummy variable for research and development activities, dummy variables for four-digit industry, Federal State dummy variables for the firm's headquarter location to account for differences in local conditions (e.g., local output and input markets), and firm-level import competition (as defined in section 2.2).

Further assuming that ω_{it} is a Markovian, $\omega_{it} = \omega_{it-t} + \xi_{it}$, where ξ_{it} denotes the idiosyncratic innovation shock in productivity, yields:

(6) $$q_{it} = \beta^l l_{it} + \beta^k k_{it} + \beta^m m_{it} + \gamma \pi_{it} + g_{it-1}(.) + \xi_{it} + \varepsilon_{it}.$$

We estimate the production function in (6) in one step following Wooldridge (2009). Thereby m_{it} and π_{it} are instrumented with their lags. Overall, the identifying moments are given by

(7) $$E\left(\xi_{it} + \varepsilon_{it} | l_{it}, \tilde{k}_{it}, \widetilde{m}_{it-1}, l_{it-1}, \tilde{k}_{it-1}, \tilde{e}_{it-1}, \mathbf{z}_{it-1}, \mathbf{\Gamma}_{it-1}, \pi_{it-1}\right) = 0,$$

where $\mathbf{\Gamma}_{it}$ collects interaction terms entering $g_{it}(.)$.

Firm total factor productivity (TFPQ) can be then recovered as:

(8) $$\omega_{it} = q_{it} - (\beta^l l_{it} + \beta^k k_{it} + \beta^m m_{it} + \gamma \pi_{it}).$$

To allow for differences in production technologies across sectors, we estimate (6) separately for NACE rev. 1.1 two-digit industries with at least 500 firm-year observations.

Table 2: Output Elasticities

NACE rev. 1.1 two-digit industries	Number of observations	Intermediate inputs	Labor	Capital	Returns to scale
15 Food products and beverages	16,576	0.68*** (0.02)	0.22*** (0.02)	0.16*** (0.04)	1.06
17 Textiles	3,917	0.76*** (0.03)	0.25*** (0.04)	0.01 (0.04)	1.05
18 Apparel, dressing, and dyeing of fur	1,366	0.77*** (0.03)	0.18*** (0.04)	0.04 (0.05)	0.99
19 Leather and leather products	774	0.75*** (0.04)	0.21*** (0.05)	0.11 (0.09)	1.07
20 Wood and wood products	2,845	0.70*** (0.03)	0.25*** (0.04)	0.01 (0.05)	0.96
21 Pulp, paper, and paper products	3,614	0.81*** (0.03)	0.18*** (0.04)	0.03 (0.02)	1.02
24 Chemicals and chemical products	7,005	0.76*** (0.02)	0.22*** (0.04)	0.06 (0.04)	1.04
25 Rubber and plastic products	7,810	0.69*** (0.03)	0.10 (0.08)	0.04 (0.03)	0.83
26 Other non-metallic mineral products	6,735	0.74*** (0.02)	0.26*** (0.03)	0.01 (0.03)	1.01
27 Basic metals	5,205	0.72*** (0.03)	0.27*** (0.04)	-0.01 (0.03)	0.98
28 Fabricated metal products	12,915	0.70*** (0.02)	0.29*** (0.05)	0.07** (0.03)	1.06
29 Machinery and equipment	14,444	0.73*** (0.02)	0.13*** (0.04)	-0.04 (0.04)	0.82
30 Electrical and optical equipment	622	0.81*** (0.09)	0.23*** (0.09)	0.28** (0.13)	1.32
31 Electrical machinery and apparatus	5,368	0.68*** (0.03)	0.26*** (0.04)	0.11*** (0.04)	1.05
32 Radio, television, and communication	1,232	0.77*** (0.05)	0.04 (0.11)	0.11 (0.12)	0.92
33 Medical and precision instruments	3,228	0.62*** (0.03)	0.23*** (0.05)	0.11 (0.08)	0.96
34 Motor vehicles and trailers	2,845	0.81*** (0.07)	0.15*** (0.05)	0.05 (0.06)	1.01
35 Transport equipment	778	0.74*** (0.06)	0.12 (0.08)	-0.29** (0.12)	0.57
36 Furniture manufacturing	4,267	0.75*** (0.03)	0.17*** (0.05)	0.04 (0.04)	0.96

Note: This table reports output elasticities for labor, capital, and intermediate inputs obtained from separate estimations of the production function in (6) for NACE rev. 1.1 two-digit industries with at least 500 firm-year observations. In all regressions time fixed effects are controlled for and inverse probability weights are used (cf., section 2.1). Standard errors are clustered at the firm level and reported in parentheses. Significance: *10 percent, **5 percent, ***1 percent.

Table 2 presents the respective output elasticities. Overall, we are able to estimate a firm-level production function for 19 different NACE rev. 1.1 two-digit industries with roughly 100,000 firm-year-observations in total. Generally, the estimated output elasticities are plausible in terms of magnitude and in line with firm-level production function estimates from other studies (De Loecker 2011; Dhyne et al. 2017; De Loecker et al. 2016;

Amiti and Konings 2007; Pavcnik 2002). Only in three NACE rev. 1.1 two-digit industries, “Basic metals (27)”, ”Machinery and equipment (29)” and “Transport equipment (35)”, the production function does not seem particularly well defined, with negative estimated output elasticities of capital. These industries are not considered in the further analysis of the impact of import competition on productivity.[7]

3. Identifying the productivity effects of import competition

To assess the effect of import competition on firm productivity, we estimate the following basic specification:

(9) $$\omega_{it} = \beta^n IC_{it-1}^n + \boldsymbol{C}'_{it-1}\gamma + \vartheta_t + \theta_{ij} + \varepsilon_{it},$$

where ω_{it} is firm total factor productivity (TFPQ) as of (8). IC_{it-1}^n is import competition from high-income or from middle- and low-income countries, $n = (High, Low)$, as of (1), lagged by one period. $\boldsymbol{C}'_{it}$ is a set of control variables: the number of products to account for systematic differences between single- and multi-product firms and export intensity (export share in total sales) to account for further firm-specific shocks on foreign markets and/or learning by exporting (Clerides et al. 1998; De Loecker 2013). ϑ_t are time fixed effects that account for aggregate shocks. θ_{ij} are firm-industry fixed effects to account for that the production function and the output elasticities are estimated separately for different industries and firms might switch industry (cf., section 2.3). Thus, we use only within-firm variation to identify the effect of import competition on firm productivity. We use (inverse probability) weight to ensure representativeness (cf., section 2.1).

Estimating (9) by OLS might yield biased results, thus compromising the causal interpretation of the results. We account for unobserved firm-specific time-invariant heterogeneity, yet the OLS might be prone to some further sources of endogeneity. For instance, the OLS estimates might be downward biased if (because of strategic behavior)

[7] Table 6 in Appendix A provides summary statistics for sample of firms used in the analysis.

import penetration is particularly strong where domestic firms are at disadvantage and have low incentives to invest in productivity.

To avoid endogeneity issues and allow causal inference, we apply an IV-2SLS strategy, following Autor et al. (2013) and Dauth et al. (2014). Specifically, we exploit that an increase in the genuine competitiveness of a country-group *n* will likely result in higher share of that country-group in the imports of other *third* countries (i.e., besides Germany) too, which is (arguably) unrelated or exogenous to the competitiveness of the domestic firms (Autor et al. 2013). Thus, we instrument (or exogenize) the import competition measures with the share of country-group n in *third* countries' total imports

(10) $$IS_{it}^{n\rightarrow third} = \sum_g \left[\left(\frac{R_{igt}}{\sum_g R_{igt}} \right) \left(\frac{M_{gt}^{n\rightarrow third}}{M_{gt}^{World\rightarrow third}} \right) \right] * 100,$$

where $M_{gt}^{n\rightarrow third}$ is the value of *third* countries' imports of product(s) g from country-group *n*, while $M_{gt}^{World\rightarrow third}$ is the value of *third* countries' total imports of product(s) g. To arrive at firm-specific instrument, we weight the share of the respective country-group in third countries' total imports of product(s) g with g's share(s) in the total sales of each individual firm, $R_{igt}/\sum_g R_{igt}$.

A necessary condition for our IV-2SLS strategy to identify the effect of import competition is that the instrument captures only changes in the foreign competitors' share on domestic markets, which are neither directly nor indirectly related to the productivity of German firms active on the same markets. However, there might still be some threats to that strategy. For instance, despite the fact that we use the strength of import competition in *third* countries, there might be (product-specific) technological developments and other shocks that are correlated across countries. Moreover, there might be policies (e.g., industrial, monetary or other policies at the EU level) that favor, deliberately or not, domestic firms and weaken the position (i.e., the share) of foreign firms on domestic and *third* country markets. In such cases the exclusion restriction (i.e., the exogeneity of the instrument) will be likely compromised since $M_{gt}^{n\rightarrow third}/M_{gt}^{World\rightarrow third}$ will be related to ω_{ijt}.

Thus, to minimize the possibility of a correlation between instrument and dependent variable, we reduce both the set of countries included in both country-groups, n, as well as the group of *third* countries used in the instrument to such that are neither too similar nor directly linked to Germany via common currency and geographical neighborhood (Dauth et al. 2014). In particular, the group of high-income countries ($n = high$) includes USA, Canada, Japan, and South Korea, the group of low-income countries ($n = low$) includes China, India, Russia, Brazil, South Africa, Argentina, Chile, Mexico, Malaysia, Turkey, Thailand, Tunisia, Bangladesh, Indonesia, Philippines, Vietnam and Pakistan, while the group of *third* countries in the instrument comprises of Norway, New Zealand, Israel, Australia, Great Britain, Sweden, and Singapore. We are aware that neither country group is complete and that such a rigorous strategy requires us to leave out a number of German trade partners, in particular EU countries, generally belonging to the group of high-income countries. Moreover, countries with negligible shares in the total imports of the German manufacturing sector (e.g., Afghanistan) are generally not considered in order to minimize the risk of introducing noise in the measures of import competition and in the instrument. Overall, however, we believe that the countries included represent the respective groups reasonably well and that we do not compromise the generalizability of the results. In fact, we rather use variation within firm (i.e., over time) in our identification and the exclusion of certain countries, though having level effects, should not affect the mechanisms driving the effects of import competition from high-income countries and from low-income countries. With respect to the group of *third* countries in the instrument, alternative definitions do not change the results qualitatively and we believe that we can adequately proxy the global competitiveness of the country(-group) n.

Finally, firm's product portfolio, which we use in (10) to arrive at firm-specific instrument, might be itself a threat to the exogeneity of the instrument. This could be the case if firms adjust their product portfolio as a reaction to and/or in anticipation of import competition (Bernard et al. 2006a; Eckel and Neary 2010). In our main specification, we use product portfolio in $t-1$ in order to make sure that we have a reasonably strong instrument. However, in a robustness check, we also use a more rigorous specification with an instrument based on the product portfolio in the first year a firm is observed in the data; for some firms this could be as earlier as 1995, while the period of analysis is 2000-2014. As product portfolio composition does not change over time, within-firm variation in this alternative instrument definition comes only from changes in the genuine competitiveness of the trade partners. However, the results do not change qualitatively (cf., section 4.1).

4. Results

4.1 Import competition and firm TFP

This section presents the results of the analysis of the impact of import competition on firm productivity (TFPQ). In general, we estimate different specifications of (9) by OLS and IV-2SLS. However, since OLS might suffer from an endogeneity problem (cf., section 3), we base our interpretations on the IV-2SLS-results.[8]

Table 3 presents the main results. Regarding import competition in general (column 2), the IV-2SLS estimates suggest that a one percentage point increase in import competition in general is associated with an increase in firm productivity by 0.2 percent.[9] The OLS estimate is smaller in magnitude and statistically insignificant (column 1), which is indeed consistent with a downward bias if import penetration is particularly pronounced in markets where domestic firms are less competitive. Distinguishing between import competition from high-income countries and from middle- and low-income countries indicates, however, that only the former is positively associated with firm productivity, thus driving the results for import competition in general. According to the IV-2SLS estimates, an increase in import competition from high-income countries by one percentage point is associated with an increase in firm productivity by 1.1 percent, while the estimate for import competition from middle- and low-income countries is virtually zero (column 4). Again, the OLS estimates are small and insignificant (column 3).

In column (5) of Table 3 we present the results of an IV-2SLS estimation, where we use product portfolio in the first year a firm is observed in the data to construct the instrument as an alternative but more robust specification to column (4), where we use information on firm product portfolio in $t-1$ for the instrument. Indeed, if firms adjust their product mix in reaction and/or in anticipation of import competition, using information from in $t-1$ might still somewhat underestimate the true effect. In column (5), the estimate for import competition from high-income countries is positive and statistically significant, while that

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[8] The first stages of the IV-2SLS estimations are reported in Appendix D.

[9] Our results are, in terms of magnitude, broadly in the range of estimates found in previous studies on the productivity effects of trade liberalization in general. Amiti and Konings (2007) estimate that a fall in industry-level output tariffs in Indonesia by one percentage point is associated with an increase in firm productivity of 0.1 to 0.6 percent. Topalova and Khandelwal (2011) find that one percent reduction in industry-level output tariffs is associated with an increase in TFP of Indian firms by 0.05 percent.

for import competition from middle- and low-income countries is virtually zero and insignificant, confirming the results from column (4) that only competition from high-income countries is associated with positive productivity effects. However, compared to column (4), where we used portfolio information in $t-1$, the estimated effect doubles, providing some indication that firms might indeed adjust product portfolio in order to escape competition. According to the point estimate, an increase in import competition from high-income countries by one percentage point is associated with an increase in firm productivity by 2.2 percent.

In column (6) of Table 3 we report the results of an IV-2SLS specification, where we use only single-product firms. In this case, identification comes from over-time variation in the competitiveness of foreign firms and not from product portfolio changes. Similar to above, we find a positive and statistically significant estimate for import competition from high-income countries and no association between productivity and import competition from middle- and low-income countries. In terms of magnitude, the point estimate for the effect of import competition from high-income countries in column (6) is nearly twice the size of that in column (4) and comparable to that in column (5).

Table 3: Import competition and firm productivity – Main results

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV-2SLS (2nd stage)	OLS	IV-2SLS (2nd stage)	IV-2SLS (2nd stage)	IV-2SLS (2nd stage)
	All firms	All firms	All firms	All firms	All firms	Single-product firms
$IC_{it-1}^{High+Low}$	-0.0001	0.0018***				
	(0.0004)	(0.0001)				
IC_{it-1}^{High}			0.0004	0.0112***	0.0222***	0.0206**
			(0.0009)	(0.0037)	(0.0071)	(0.0104)
IC_{it-1}^{Low}			-0.0003	-0.0005	-0.0008	0.0001
			(0.0005)	(0.0010)	(0.0015)	(0.0018)
Firm controls $_{it-1}$	YES	YES	YES	YES	YES	YES
Firm ∗ Industry FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Observations	78,414	78,414	78,414	78,414	73,212	22,729
R^2	0.986	0.986	0.986	0.985	0.984	0.982
First-stage F-test	-	142.00	-	36.89	13.13	12.09
Number of firms	16,925	16,925	16,925	16,925	15,853	5,467

Note: This table reports results from estimating equation (9) by OLS and by IV-2SLS (2nd stage); the first stage results from the IV-2SLS estimations are reported in Table 7 in Appendix D. Import competition is defined as in (1). The group of high-income countries (for IC^{High}) includes USA, Canada, Japan, and South Korea. The group of low-income countries (for IC^{Low}) includes China, India, Russia, Brazil, South Africa, Argentina, Chile, Mexico, Malaysia, Turkey, Thailand, Tunisia, Bangladesh, Indonesia, Philippines, Vietnam and Pakistan. Instrument/s is/are constructed according to (10). The *third* countries-group (for the instrument) consists of Norway, New Zealand, Israel, Australia, Great Britain, Sweden, and Singapore. In all regressions inverse probability weights are used (cf., section 2.1). Included firm-level controls are: export intensity (exports over sales) and number of products (not in column (6)). In columns (1) and (2) the OLS and IV-2SLS results of an estimation of the effects of total import competition are reported. Columns (3) and (4) report the OLS and IV-2SLS results for the impact of import competition from high-income countries and from middle- and low-income countries separately. In columns (2) and (4) instrument is constructed using product portfolio composition in $t-1$ (cf., section 3 and equation (10)). Column (5) is alternative to (4) as instruments are constructed using constant product portfolio composition in the first year a firm is observed in the data, rather than in $t-1$. Column (6) presents the IV-2SLS results for single-product firms. Standard errors are clustered at the firm level. Significance: *10 percent, **5 percent, ***1 percent.

In Table 4 we report the results of an analysis of the importance of import competition from low-income countries and from high-income countries with respect to core and non-core products. This way, we also shed some more light on whether the previous findings that only import competition from other industrialized high-income countries, but not from developing low-income countries is associated with a productivity increase by firms (cf., Table 3) could be driven by the possibility that import competition from the two types of countries differs systematically across products of different importance for the domestic firms. On the one hand, firms are typically organized around a distinct product or comparably small set of specific and relatively closely related products and competences and, within a firm, higher rank products are of higher quality and price, using higher quality and relatively more expensive resources (cf., Manova and Yu 2017; De Loecker et al. 2016). In fact, we find that firms make on average about two thirds of their total revenue with one distinct product of few very closely related products; if we consider also single-product firms, this figure raises to about three fourths (cf., Figure 1 in the Appendix). Hence, firms' incentives to invest in productivity as a reaction to competition might depend on whether it threatens firms' core competences and/or their main business, where the costs of exit (e.g., the devaluation of inputs) will be larger. On the other hand, the evidence provided in section 2.2 (cf., Table 1) suggests that imports from other high-income countries tend to be relatively capital- and technology-intensive, complex and differentiable, on which also Germany (being also an industrialized country) generally tends to specialize. On the opposite, imports from low-wage countries are typically simple goods that use 'standard' technologies, can be produced with relative unskilled and cheap labor, and more often among the non-core product of domestic firms since these are at general disadvantage in such areas. Moreover, using our data we find that competition from industrialized high-income countries with respect to core products is on average seven percent (and statistically significantly) higher than for non-core products, while relatively small (two percent) and statistically insignificant difference between import competition from developing low-income countries with respect to core and with to non-core products.

Table 4 presents the results for the effects of import competition with respect to core- and non-core products of multi-product firms. For each firm, the core product is the one with the largest revenue share, while all other products are non-core products. The (IV-2SLS) estimates indicate a positive association between firm TFPQ and import competition only when the core markets of domestic firms are threatned by foreign competitors from other industrialized, high-income countries. Import competition from low-income countries with respect to core products is not associated with an increase in productivity by domestic firms. Import competition with respect to non-core products does not incentivize domestic firms to increase productivity, regardless of whether from high-income or from low-income countries.

Table 4: Import competition and firm productivity – Core and non-core products

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV-2SLS (2nd stage)	OLS	IV-2SLS (2nd stage)	IV-2SLS (2nd stage)	IV-2SLS (2nd stage)
$IC\_Core_{it-1}^{High+Low}$	0.0001	0.0009			0.0013	
	(0.0004)	(0.0007)			(0.0045)	
$IC\_nonCore_{it-1}^{High+Low}$	-0.0006	0.0001			-0.0007	
	(0.0005)	(0.0011)			(0.0048)	
$IC\_Core_{it-1}^{High}$			-0.0000	0.0064***		0.0165*
			(0.0009)	(0.0025)		(0.00998)
$IC\_nonCore_{it-1}^{High}$			-0.0006	0.0026		-0.0053
			(0.0013)	(0.0030)		(0.0074)
$IC\_Core_{it-1}^{Low}$			0.0002	-0.0007		-0.0093
			(0.0005)	(0.0009)		(0.0068)
$IC\_nonCore_{it-1}^{Low}$			-0.0006	-0.0003		0.0080
			(0.0005)	(0.0013)		(0.0071)
Firm controls $_{it-1}$	YES	YES	YES	YES	YES	YES
Firm * Industry FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Observations	53,696	53,696	53,696	53,696	45,559	45,559
R^2	0.987	0.987	0.987	0.987	0.986	0.986
First-stage F-test	-	129,00	-	19.47	5.81	3.38
Number of firms	11,451	11,451	11,451	11,451	9,690	9,690

Note: This table reports results from estimating equation (9) by OLS and by IV-2SLS (2nd stage); the first stage results from the IV-2SLS estimations are reported in Table 8 in Appendix D. Import competition is defined as in (1). For each firm, the core product is the one with the largest revenue share, while all other products are non-core products. The group of high-income countries (for IC^{High}) includes USA, Canada, Japan, and South Korea. The group of low-income countries (for IC^{Low}) includes China, India, Russia, Brazil, South Africa, Argentina, Chile, Mexico, Malaysia, Turkey, Thailand, Tunisia, Bangladesh, Indonesia, Philippines, Vietnam and Pakistan. Instrument are constructed according to (10). The *third* countries-group (for the instrument) consists of Norway, New Zealand, Israel, Australia, Great Britain, Sweden, and Singapore. In all regressions inverse probability weights are used (cf. section 2.1). Included firm-level controls are: export intensity (exports over sales) and number of products. In columns (1) and (2) the OLS and IV-2SLS results of an estimation of the effects of total import competition are reported. Columns (3) and (4) report the OLS and IV-2SLS results for the impact of import competition from high-income countries and from middle- and low-income countries separately. In columns (2) and (4) instruments are constructed using product portfolio composition in $t-1$ (cf., section 3 and equation (10)). Column (5) and (6) are alternative to (2) and (4) as instruments are constructed using constant product portfolio composition in the first year a firm is observed in the data, rather than in $t-1$. Standard errors are clustered at the firm level. Significance: *10 percent, **5 percent, ***1 percent.

4.2 Import competition and firm R&D, output and employment

To better understand the effects of import competition, particularly the differential impact of import competition from different types of countries, in this section we study the effects of import competition on firms' R&D, sales, and employment. On one hand, R&D is regarded a key vehicle to increase productivity and regain market shares. In Bloom et al. (2013) import competition reduces the opportunity costs of innovating by releasing inputs 'trapped' in the production of 'old' goods. One the other hand, failing to increase productivity in response to competition results in decline or even exit. Hence, simultaneously looking at productivity, R&D, sales and employment effects will help better understand the nature and the effects of competition.

Table 5: Import competition and firm R&D, output and employment

	(1)	(2)	(3)
	R&D Expenditures	Output, log	Employment (fte), log
	$R\&D_{it}$	q_{it}	l_{it}
IC_{it-1}^{High}	222,201	0.0010	-0.0052
	(439,359)	(0.0067)	(0.0041)
IC_{it-1}^{Low}	-98,976*	-0.0059***	-0.0031**
	(54,844)	(0.0023)	(0.0014)
Firm controls $_{it-1}$	YES	YES	YES
Firm ∗ Industry FE	YES	YES	YES
Time FE	YES	YES	YES
Observations	78,414	78,414	78,414
Number of firms	16,925	16,925	16,925
R^2	0.985	0.985	0.985
First-stage F-test	36.89	36.89	36.89

Notes: This table reports the second stage results of IV-2SLS estimations; the first stage results from the IV-2SLS estimations are reported in Table 9 in Appendix D. The dependent variables in columns (1)-(3) are respectively a R&D expenditures in €, log quasi-physical output (revenue deflated with a firm-specific deflator as in (3) in section 2.3), and log employment in full time equivalents (fte). All regressions are weighted using inverse probability weights and include controls for firms' export intensity and number of products. Standard errors are clustered at the firm level. Significance: *10 percent, **5 percent, ***1 percent.

Table 5 reports the results of an IV-2SLS estimation of the effects of import competition on firm R&D expenditures, sales and employment.[10] We interpret the sales of a firm as

[10] We report only the IV-2SLS estimates since OLS might be biased. See also Table 3 and Table 4 as well as section 3 for a discussion. OLS results are available on request. Though R&D is measured in Euros and therefore whole-numbered, we assess the association between import competition and R&D by means of linear estimation techniques due to the presence of a large amount of firm dummies (i.e. fixed-industry effects) and two endogenous regressors that need to be instrumented (Wooldridge 2010; Cameron and Triverdi 2013).

quasi-physical output, since these are deflated with a firm-specific price deflator (cf., section 2.3). Regarding import competition from middle- and low-income countries, the IV-2SLS estimates reveal a negative association with R&D expenditures (cf., column 1 in Table 5). As to the degree, in which productivity depends on R&D, these findings correspond with the lack of association between import competition from low-income countries and productivity reported in Table 3. A possible explanation is that R&D is too costly or ineffective in the case of simple and labor-intensive products from low-income and (low-wage) countries. 'Unable' to compete, domestic firms decline in terms of output and employment as indicated by the negative and statistically significant estimates for the effect of import competition from low-income countries on output and employment (cf., columns 2 and 3 in Table 5).

Regarding import competition from high-income countries, we find essentially no effects on firm output and employment (cf., column 2 and 3 in Table 5). This is consistent with the increase in productivity as a result of competition reported in Table 3. Yet, though imports from high-income countries tend to threaten capital- and technology-intensive domestic products, we find no statistically significant association with R&D. A possible explanation is that improving productivity must not be confined to R&D. For instance, while Bloom et al. (2017) refer to management as a 'technology' and Bloom et al. (2014) suggest that management practices explain a substantial fraction of productivity differences, Bloom et al. (2015) show how competition might affect the quality of management. Our findings are also consistent with a reduction in arbitrary X-inefficiencies within firms (Leibenstein 1966).

5. Conclusions

In this paper we analyze the impact import competition on (within-)firm productivity. We use comprehensive administrative firm-level panel data from German manufacturing for the period 2001-2014. The data contain information on the prices and quantities of firms' final products, which is a twofold advantage. On the one hand, we assess the firm-specific strength of import competition, which, compared to industry-wide measures of import competition, helps us explicitly disentangle its effects from further productivity enhancing channels if the industry imports are final products for some firms but intermediates for other firms in the same industry. One the other hand, it allows us to derive a quantity-based productivity measure (TFPQ) that is not confounded by firm-specific factors that influence prices (e.g., market power). We assess the effects of import competition on firm productivity by estimating a linear panel model with firm-specific fixed effects and additionally apply an IV-2SLS approach that gives us more confidence in drawing causal inference. Moreover, to better understand the effects of import competition, we also look at its effects on R&D, sales and employment.

We document differential impact on firm productivity from import competition from low-income countries and from high-income countries, which we attribute to differences in the (in)ability of domestic firms to cope with competition on products with different characteristics from different countries; the total effect of import competition is obviously a mixture of the effect of competition from low-income countries and from high-income countries. In particular, we show that imports from low-income countries are typically relatively simple, non-differentiable and produced with ‘standard’ technologies and more of cheap labor. This puts manufacturing firms from industrialized, high-income countries, like Germany, which face relatively high and downward-rigid wages, at a disadvantage. Accordingly, import competition does not create positive incentive for the affected firms to invest in costly innovation and productivity improvement, and is associated with drop in output and employment. Imports from industrialized, high-income countries are, on the opposite, typically relatively capital- and knowledge-intensive, high-quality (vertically) differentiable products, at which also German firms are comparably good. Accordingly, we find that import competition from high-income countries spurs productivity improvement and is not associated with a drop in sales or employment.

The empirical evidence provided in this paper adds to a more complete and at the same time more differentiated picture on the effects of import competition, which complements existing research but is also important for policy. Complementing other frameworks that relate (aggregate) productivity gains from trade and globalization to between-firm dynamics (e.g., Melitz 2003; Melitz and Ottaviano 2008; Mayer et al. 2014), we illuminate additional within-firm productivity effects. This raises the questions about the relative importance of between- and within-firms channels, and the policy-relevant factors that affect these. Moreover, the findings that import competition is not necessarily associated with increase in R&D as a mean to escape it, raises the question about the potential role of further, non-technological measures to improve productivity (or reduce X-inefficiency). In this line of thinking, linking international trade, globalization and import competition with managerial and organizational practices and/or other types of intangible assets, which have generally also been found important for firm performance (cf., Bloom et al. 2017), may provide additional insights. Similarly, our findings point to the importance of product portfolio optimization as a reaction to import competition, so that further empirical research would be beneficial to complement the literature (Bernard et al. 2010, 2011; Nocke and Yeaple 2014; Eckel and Neary 2010).

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Appendix

Appendix A: Firm-specific price deflator

We construct a firm-specific price index to deflate firm revenues. In particular, we closely follow Eslava et al. (2004) and construct a firm-specific Tornqvist index for the price of firm's composite (i.e., multiple product) output

$$P_{it} = \prod_{g=1}^{n} \left(\frac{p_{igt}}{p_{igt-1}}\right)^{\frac{1}{2}(s_{igt}+s_{igt-1})} P_{it-1},$$

where p_{igt} is the price of good g and s_{igt} is the share of this good in the total sales of firm i in period t. Thus, the growth of the index is the product of the individual products' price growths, each weighted with the average sales share of that product over the current and the last years. Following Eslava et al. (2004), we use the first year available in the data as our base year, i.e. $P_{t=2000} = 100$, while for firms entering after 2000, we use the industry average as a starting value. Again in line with Eslava et al. (2004), we replace missing product price information with an average price for the respective product.

Appendix B: Construction of capital stock series

The *AFiD* data do not contain information on capital stock but on yearly investment. As typical in the literature in such cases, we apply the perpetual inventory method to obtain the capital stock. To estimate the initial capital stock of the firm, we combine information on the value of yearly depreciations of firms, τ_{it}, which is also available in the *AFiD* data and further information from the Federal Statistical Office on the average lifetime of different capital goods in industries j, $D_{jt}(\Theta)$, where $\Theta = (equipment, buildings)$, which contains information about their 'real' depreciation rate.[11] As standard in the literature, we assume that capital in industry j depreciates at a constant rate, $\delta_{j0}^{\Theta} = \delta_{jt}^{\Theta}$, and that it is fully destroyed (depreciated) at the end of its lifetime. Thus, we can define the amount of capital which depreciated during the production process in industry j as

$$\varphi_{jt}^{\Theta} = \delta_{jt}^{\Theta} K_{jt}^{\Theta},$$

The average lifetime of a capital stock Θ purchased in $t = 0$ then equals

$$D_{j0}(\Theta) = \frac{1}{K_{j0}^{\Theta}} \sum_0^{\infty} \varphi_{jt}^{\Theta} t = \frac{1}{K_{j0}^{\Theta}} \sum_0^{\infty} \left(\delta_{jt}^{\Theta} K_{jt}^{\Theta}\right) t.$$

Assuming a linear capital depreciation, $K_{jt}^{\Theta} = K_{j0}^{\Theta}\left(1 - \delta_{j0}^{\Theta}\right)^t$, and substituting it above yields

$$D_{jt}(\Theta) = \frac{\delta_{j0}^{\Theta}}{\ln(1-\delta_{j0}^{\Theta}) * \ln(1-\delta_{j0}^{\Theta})}.$$[12]

As $D_{jt}(\Theta)$ is known, we can recover δ_{j0}^{Θ} by solving this expression numerically for each year and each capital type, $\Theta = (equipment, buildings)$. This generates two depreciation rates for each point in time. We then define a composite industry-specific

[11] Essentially, we augment the capital stock calculation approach in Mueller (2008) by backing out the implied depreciation rate. Moreover, using information on the actual lifetime of capital goods yields a closer approximation of the capital actually used in firms' production activities than capital stocks based on book values if firms (i) buy/sell capital goods not to market prices and (ii) have incentives to depreciate their accounting capital excessively (House and Shapiro 2008).

[12] Prove is available on request.

depreciation rate by using the industry-wide shares of equipment and buildings as weights. Finally, we simplify by assuming that the depreciation rate for the entire capital stock in each period equals the depreciation rate of newly purchased capital, i.e. $\delta_{j0} = \delta_{jt}$.

Having calculated δ_{jt}, we can recover the initial capital stock for every firm by using information on the value of yearly depreciations, τ_{it}, from the *AFiD*-database

$$K_{it} = \tau_{it}/\delta_{jt}.$$

Now the capital series can be constructed according to

$$K_{it} = K_{it-1}\left(1 - \delta_{jt-1}\right) + I_{it-1},$$

where I_{it} is firm investment.[13]

[13] We deflate τ_{it} and I_{it} respectively using industry-specific capital depreciation and investment deflators provided by the Federal Statistical Office of Germany.

Appendix C: Sample summary statistics

Table 6: Summary statistics of firms in the sample, 2001-2014

	Mean	SD	P25	Median	P75	N
Firm productivity	2.82	0.85	2.26	2.72	3.21	78,414
Revenue (in 1,000€, deflated)	97,600	121,000	5,443	14,200	44,200	78,414
Full-time equivalents	351.10	2,773.9	47	98	244	78,414
Capital stock (in 1,000 €, deflated)	61,000	613,000	2,662	8,220	28,200	78,414
Intermediate expenditures (in 1,000 €, deflated)	70,700	973,000	3,088	8,734	28,800	78,414
Export share in total sales (%)	23.86	25.16	0.54	16.46	40.31	78,414
Export status dummy	0.78	0.42	1	1	1	78,414
Number of products	4.04	8.53	1	2	4	78,414

Note: This table reports summary statistics for sample firms used in the estimation of the effects of import competition on productivity as of equation (9).

Appendix D: First stage regressions

Table 7: First stages of the estimation of the effect of import competition on firm productivity (cf., Table 3 in main text)

	(2)	(4.1)	(4.2)	(5.1)	(5.2)	(6.1)	(6.2)
	$IC_{it-1}^{High+Low}$	IC_{it-1}^{High}	IC_{it-1}^{Low}	IC_{it-1}^{High}	IC_{it-1}^{Low}	IC_{it-1}^{High}	IC_{it-1}^{Low}
$IS_{it-1}^{High+Low\rightarrow third}$	0.235***						
	(0.0197)						
$IS_{it-1}^{High\rightarrow third}$		0.0995***	0.0314***	0.0669***	0.0188	0.0591***	0.0097
		(0.0117)	(0.0111)	(0.0132)	(0.0126)	(0.0121)	(0.0137)
$IS_{it-1}^{Low\rightarrow third}$		0.0156***	0.279***	0.0071	0.230***	0.0064	0.247***
		(0.0051)	(0.0224)	(0.00535)	(0.0283)	(0.0054)	(0.0312)
Firm controls $_{it-1}$	YES	YES	YES	YES	YES	YES	YES
Firm * Industry FE	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES
R^2	0.950	0.927	0.958	0.943	0.954	0.959	0.961
Observations	78,414	78,414	78,414	73,212	73,212	22,729	22,729
Number of firms	16,925	16,925	16,925	15,853	15,853	5,467	5,467

Note: First stages of the estimation of the effect of import competition on firm productivity (cf., Table 3 in main text). Column (2) is the first stages of column (2) in Table 3 in the main text. Columns (4.1)-(6.2) are the first stages of columns (4)-(6) in Table 3 in the main text. Standard errors clustered at firm-level (in parentheses). *** p<0.01, ** p<0.05, * p<0.1. Import competition in general, IC_{it-1}^{n}, is defined according to (1) as the share (in domestic production of German manufacturing firms) of imports from country group n. The group of high-income countries (for IC_{it-1}^{High}) includes USA, Canada, Japan, and South Korea. The group of low-income countries (for IC_{it-1}^{Low}) includes China, India, Russia, Brazil, South Africa, Argentina, Chile, Mexico, Malaysia, Turkey, Thailand, Tunisia, Bangladesh, Indonesia, Philippines, Vietnam and Pakistan. Instruments ($IS_{it-1}^{High+Low\rightarrow third}$, $IS_{it-1}^{High\rightarrow third}$, $IS_{it-1}^{Low\rightarrow third}$) are constructed according to (10) as the share of the respective country group in the total imports of *third* countries (Norway, New Zealand, Israel, Australia, Great Britain, Sweden and Singapore) (cf., Section 3 for details). In columns (5.1) and (5.2) instruments are based on information on product portfolio in the first year a firm is observed in the data

Table 8: First stages of the estimation of the effect of import competition with respect to core and non-core products on firm productivity (cf., Table 4 in main text)

	(2.1)	(2.2)	(4.1)	(4.2)	(4.3)	(4.4)
	$IC\_Core_{it-1}^{High+Low}$	$IC\_nonCore_{it-1}^{High+Low}$	$IC\_Core_{it-1}^{High}$	$IC\_nonCore_{it-1}^{High}$	$IC\_Core_{it-1}^{Low}$	$IC\_nonCore_{it-1}^{Low}$
$IS\_Core_{it-1}^{High+Low\rightarrow third}$	0.266***	-0.0067				
	(0.0275)	(0.0127)				
$IS\_nonCore_{it-1}^{High+Low\rightarrow third}$	-0.00126	0.238***				
	(0.00972)	(0.0150)				
$IS\_Core_{it-1}^{High\rightarrow third}$			0.138***	0.0308*	-0.0091	-0.0049
			(0.0158)	(0.0186)	(0.0101)	(0.0102)
$IS\_nonCore_{it-1}^{High\rightarrow third}$			0.0229**	0.295***	-0.0070	0.0041
			(0.0093)	(0.0257)	(0.0047)	(0.0116)
$IS\_Core_{it-1}^{Low\rightarrow third}$			-0.0215**	0.0158**	0.152***	0.0111
			(0.0091)	(0.0078)	(0.0166)	(0.0088)
$IS\_nonCore_{it-1}^{Low\rightarrow third}$			-0.0056	0.0021	0.018***	0.270***
			(0.0085)	(0.0131)	(0.0067)	(0.0185)
Firm controls $_{it-1}$	YES	YES	YES	YES	YES	YES
Firm * Industry FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
R^2	0.927	0.941	0.906	0.927	0.904	0.946
Observations	53,696	53,696	53,696	53,696	53,696	53,696
Number of firms	11,451	11,451	11,451	11,451	11,451	11,451

	(5.1)	(5.2)	(6.1)	(6.2)	(6.3)	(6.4)
	$IC\_Core_{it-1}^{High+Low}$	$IC\_nonCore_{it-1}^{High+Low}$	$IC\_Core_{it-1}^{High}$	$IC\_nonCore_{it-1}^{High}$	$IC\_Core_{it-1}^{Low}$	$IC\_nonCore_{it-1}^{Low}$
$IS\_Core_{it-1}^{High+Low\rightarrow third}$	0.128***	0.0656***				
	(0.0258)	(0.0132)				
$IS\_nonCore_{it-1}^{High+Low\rightarrow third}$	0.0591***	0.117***				
	(0.0123)	(0.0143)				
$IS\_Core_{it-1}^{High\rightarrow third}$			0.0786**	0.0084	0.0364**	0.0059
			(0.0320)	(0.0205)	(0.0152)	(0.0116)
$IS\_nonCore_{it-1}^{High\rightarrow third}$			0.0108	0.0161*	0.0772***	0.0007

			(0.0085)	(0.0088)	(0.0175)	(0.0097)
$IS\_Core_{it-1}^{Low \to third}$			0.0137	0.130***	0.0004	0.0709***
			(0.0109)	(0.0231)	(0.0070)	(0.0127)
$IS\_nonCore_{it-1}^{Low \to third}$			-0.0044	0.0866***	-0.0064	0.153***
			(0.0086)	(0.0161)	(0.0067)	(0.0181)
Firm controls $_{it-1}$	YES	YES	YES	YES	YES	YES
Firm * Industry FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
R^2	0.918	0.927	0.900	0.913	0.893	0.930
Observations	45,559	45,559	45,559	45,559	45,559	45,559
Number of firms	9,690	9,690	9,690	9,690	9,690	9,690

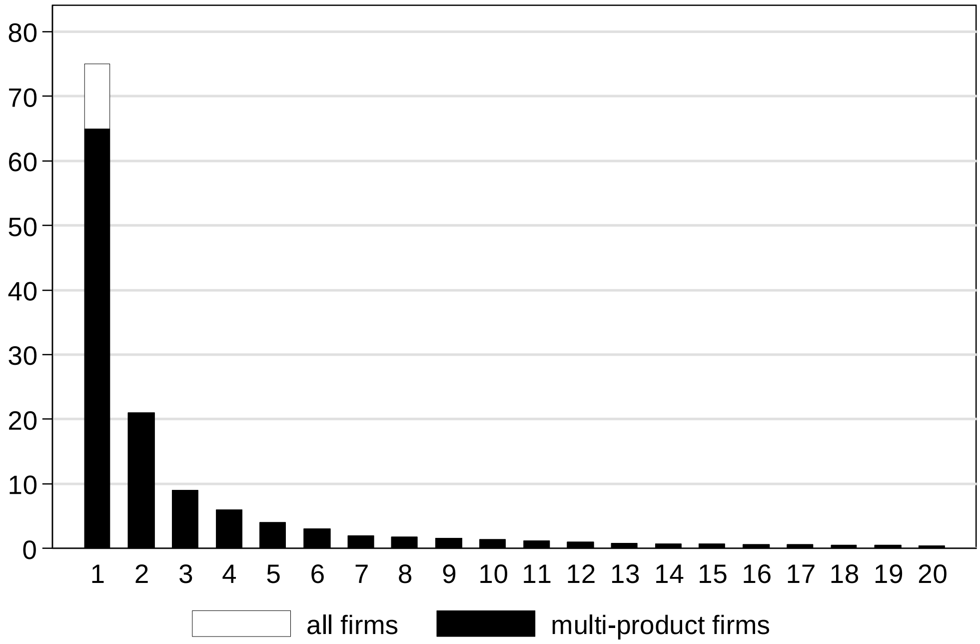
Note: First stages of the estimation of the effect of import competition with respect to core and non-core products on firm productivity (cf., Table 4 in main text). Columns (2.1)-(6.4) are the first stages of columns (2), (4), (5) and (6) in Table 4 in the main text. Standard errors clustered at firm-level (in parentheses). *** p<0.01, ** p<0.05, * p<0.1. Import competition in general, IC_{it-1}^{n}, is defined according to (1) as the share (in domestic production of German manufacturing firms) of imports from country group n. The group of high-income countries (for IC_{it-1}^{High}) includes USA, Canada, Japan, and South Korea. The group of low-income countries (for IC_{it-1}^{Low}) includes China, India, Russia, Brazil, South Africa, Argentina, Chile, Mexico, Malaysia, Turkey, Thailand, Tunisia, Bangladesh, Indonesia, Philippines, Vietnam and Pakistan. Instruments ($IS\_Core_{it-1}^{High+Low \to third}$, $IS\_nonCore_{it-1}^{High+Low \to third}$, $IS\_Core_{it-1}^{High \to third}$, $IS\_nonCore_{it-1}^{High \to third}$, $IS\_Core_{it-1}^{Low \to third}$, $IS\_nonCore_{it-1}^{Low \to third}$) are constructed according to (10) as the share of the respective country group in the total imports of *third* countries (Norway, New Zealand, Israel, Australia, Great Britain, Sweden and Singapore) (cf., Section 3 for details). In columns (2.1)-(4.4) instruments are based on information on product portfolio in $t-1$, while in columns (5.1)-(6.4) instruments are based on information on product portfolio in the first year a firm is observed in the data.

Table 9: First stages of the estimation of the effect of import competition on firm output, employment and R&D (cf., Table 5 in main text)

	(1.1)	(1.2)	(2.1)	(2.2)	(3.1)	(3.2)
	IC_{it-1}^{High}	IC_{it-1}^{Low}	IC_{it-1}^{High}	IC_{it-1}^{Low}	IC_{it-1}^{High}	IC_{it-1}^{Low}
$IS_{it-1}^{High\rightarrow third}$	0.0995***	0.0314***	0.0995***	0.0314***	0.0995***	0.0314***
	(0.0117)	(0.0111)	(0.0117)	(0.0111)	(0.0117)	(0.0111)
$IS_{it-1}^{Low\rightarrow third}$	0.0156***	0.279***	0.0156***	0.279***	0.0156***	0.279***
	(0.0051)	(0.0224)	(0.0051)	(0.0224)	(0.0051)	(0.0224)
Firm controls $_{it-1}$	YES	YES	YES	YES	YES	YES
Firm * Industry FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
R^2	0.927	0.946	0.927	0.946	0.927	0.946
Observations	78,414	78,414	78,414	78,414	78,414	78,414
Number of firms	16,925	16,925	16,925	16,925	16,925	16,925

Note: First stages of the estimation of the effect of import competition on firm productivity (cf., Table 5 in main text). Columns (1.1)-(3.2) are the first stages of columns (1)-(3) in Table 5 in the main text. Standard errors clustered at firm-level (in parentheses). *** p<0.01, ** p<0.05, * p<0.1. Import competition in general, IC_{it-1}^{n}, is defined according to (1) as the share (in domestic production of German manufacturing firms) of imports from country group n. The group of high-income countries (for IC_{it-1}^{High}) includes USA, Canada, Japan, and South Korea. The group of low-income countries (for IC_{it-1}^{Low}) includes China, India, Russia, Brazil, South Africa, Argentina, Chile, Mexico, Malaysia, Turkey, Thailand, Tunisia, Bangladesh, Indonesia, Philippines, Vietnam and Pakistan. Instruments ($IS_{it-1}^{High\rightarrow third}$, $IS_{it-1}^{Low\rightarrow third}$) are constructed according to (10) as the share of the respective country group in the total imports of *third* countries (Norway, New Zealand, Israel, Australia, Great Britain, Sweden and Singapore) (cf., Section 3 for details). Instruments are based on information on product portfolio in $t-1$.

Figure 1: Revenue share by product



Note: Revenue share by product; averages over firms. Figures do not need to add up to 100 percent, since firms have different number of products. Cut off at 20 products for convenience.

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