Import Competition and Firm Innovation: Evidence from German Manufacturing*

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Abstract

This study analyzes empirically the effects of import competition measured at the level of individual firms on the innovative activities of firms using administrative panel data from German manufacturing. We distinguish between import competition from high-income countries and from middle- and low-income countries to account for differences in (i) the R&D intensity and the innovation potential of the threatened products, and (ii) the type of competition. Imports from high-income countries are relatively capital-intensive and technologically more sophisticated goods, at which German firms tend to be relatively good, whereas imports from middle- and low-wage countries are relatively labor-intensive and technologically less sophisticated goods, at which German firms tend to generally be at disadvantage. We find that import competition from high-income countries is positively associated with an increase in the number of products of firms, while import competition from middle- and low-income countries only marginally so. However, while the association between import competition from high-income countries and R&D inputs (expenditures and employees) tends to be generally positive, the association between import competition from middle- and low-income countries and R&D inputs tends to be negative, presumably because the innovation potential of the threatened products is not sufficient to offset the cost disadvantages of domestic firms.

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1. Introduction

Trade liberalization and intensified competition due to imports is largely thought to increase in productivity. However, it might be also accompanied by a process of structural transformation. In fact, previous research findings has documented negative effects from import competition on the labor markets in industrialized countries, which has raised heated debates in both academic and policy circles (cf., Autor et al. 2013; Dauth et al. 2014). Yet, there is comparably less evidence on the adjustment reactions and the undergoing mechanisms at the level of the individual firms (cf., Shu and Steinwender 2019 for an excellent overview of existing research and open questions).

We analyze empirically the effects of import competition on R&D and innovation activities at the firm level. Competition threatens firms' rents and even their existence. In theory, to escape competition, firms do costly R&D to develop new and/or better products (Aghion et al. 2004, 2005, 2009 and for an overview Holmes and Schmitz 2010). While this can ultimately result in an increase in the efficiency and productivity of firms, it might also have important consequences for the organization of production, the amount and type/quality of inputs employed by firms, particularly labor. Hence, more evidence on the firm reactions will ultimately help better understand more general patterns of economic change.

We attempt to make several contributions. We investigate the effects of import competition on various measures of firm R&D and innovation activities: R&D expenditures, R&D employment, and number of products and patents. While R&D expenditures and R&D employment can be seen as 'inputs' in the innovation processes, the number of product actually produced by a firm is one direct measure for the outcome of a 'horizontal' innovation process (or portfolio diversification). Hence, looking simultaneously at various aspects helps us arrive at a more complete understanding of the role of import competition in innovation.

We distinguish between import competition from high-income countries and from middle- and low-income countries to account for that imports from different types of countries threaten products with different R&D intensity and innovation potential and likely imply different types of competition, and, therefore,

differences in the incentives of domestic firms to invest in R&D, and differences in the strategies to cope with competition in general. We show that imports from high-income countries threaten mainly relatively capital- and R&D-intensive domestic products, whereas imports from middle- and low-income countries threaten mainly relatively labor-intensive products. This corresponds to previous research documenting, in line with the relative comparative advantages framework in international economics, that middle- and low-income countries export—compared to high-income countries—rather labor-intensive goods that use comparably 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).

We use high-quality comprehensive, administrative yearly data from German manufacturing firms (not plants) which allows us to construct an unbalanced panel of ca. unique 16.000 firms for the period 2000-2014. The data contain information on R&D expenditures, R&D employees and final, actually produced products (not resale goods). Using the firm-product level information in the data and information on imports at the product level from Comtrade, we construct a firm-specific import competition measure based on the share of foreign firms in total domestic production of only the final goods of each individual domestic firms. This allows us (i) to take into account that competition takes place on firm-specific markets rather than within (broadly defined) industries, which minimizes measurement errors due to firm heterogeneity, and (ii) to separate the effect of import competition from that of other channels such as access to better inputs and/or embodied technologies if, for instance, competition is measured at the industry-level and the imports of an industry are final output for some firms in that industry and inputs for other firms in the same industry (Young 1991; Kasahara and Rodrigue 2008; Lileeva and Trefler 2010; Goldberg et al. 2010; Halpern et al. 2015; Ahn and Duval 2017).

We estimate the effects of import competition on firm R&D, using only within firm variation, while controlling for firm-specific time-invariant heterogeneity (i.e., firm fixed effects). To strengthen causal inference, we apply an IV-2SLS strategy and instrument the domestic imports that are relevant for each individual

firm with the same type of imports of third countries from the same set of trade partners. Since we keep the product portfolios of domestic firms constant over time, the instrument reflects the genuine competitiveness of the imports and is (arguably) exogenous (i.e., unrelated to the competitiveness and the R&D intensity of domestic firms) (Autor et al. 2013).

Overall, our results are as follows. We find a negative association between import competition from middle- and low-income countries and R&D expenditures and R&D employees, while the findings with respect to import competition from high-income countries are mostly positive, yet not always statistically significant. Regarding the number of final products of firms, we find a mostly positive association with both import competition from high-income industrialized countries as well as competition from middle- and low-income countries. However, the effects of import competition from high-income countries are an order of magnitude larger than these of import competition from middle- and low-income countries. Regarding patents, we find no association with import competition from either type of countries: the estimates are negative, but virtually close to zero in terms of magnitude and statistically insignificant.

This paper connects to several lines of previous work. The results for the effects on R&D expenditures and R&D employment are in line with the Schumpeterian literature on competition and innovation (Aghion et al. 2004, 2005, 2009) and indicate that it is important to take the type and origin of competition into account. In this rather general framework, the incentives to do costly R&D and innovation to escape competition depend on how easy/costly it is for a firm to keep up with or leapfrog the competitor. Following this line of thinking, for high-wage facing German manufacturing firms, the innovation (e.g., quality improvement) and/or cost cutting potential of costly R&D can not compensate the price disadvantages when competing on relatively technologically less sophisticated (using ‘standard’ technologies) but more labor-intensive goods with firms from middle- and low-income countries rich in simple and cheap labor. One the opposite, there are positive effects from competition from other industrialized, high-income countries, because the domestic firms have relative advantages and are relatively more ‘competent’ at the same type of comparably

capital-intensive, technologically sophisticated, complex, and (vertically) differentiable goods and products.

We find generally positive association between import competition and the number of products firms produce, which suggests that firm might try escape competition by adding new products in their portfolios. Yet, these findings are much more pronounced in the case of import competition from high-income countries that in the case of competition from middle- and low-income countries.

Taken together, the result suggest that high-wage facing firms from industrialized countries react to import competition from other high-income countries by adding new products and diversifying, which is accompanied by a moderate increase in the level of investment in technical/formal R&D. In the case of import competition from middle- and low-income countries, there is only very weak evidence for diversification and partly negative effects on R&D inputs, suggesting rather cost-cutting behavior. The findings raise the question about the possible role of further intangible, but non-technical R&D related dimensions such as organizational, managerial and other practices, along which firms might adjust in reaction to competition (van Reenen 2011; Bloom et al. 2015; Schmidt 1997).

We also complement previous research that has looked at the effects of Chinese imports on innovation, in particular patenting. Bloom et al. (2016) regress, in a long-term differences specification (5 years changes), the number of patents per firm in an industry on China's share in the total imports of the industry, using Bureau van Dijk's Amadeus data (BvD-Amadeus) on 8,000 firms across 12 European countries (spanning ca. 1,500 industry-country pairs) and find that Chinese import competition stimulates patenting by firms in the respective industry. Qualitatively similar results are reported when R&D expenditures are used (cf., footnote 22 in Bloom et al. 2016). According to the authors, the increase in innovation in reaction to competition from low-wage countries, albeit firms from industrialized countries typically face cost disadvantages, is that the factors used for production of the goods hit by import competition from low-wage countries are expensive but 'trapped' within the firm (e.g., firm-specific human capital) due to moving costs (Bloom et al. 2013, 2019). A negative demand shock

will leave them in the firm but their opportunity cost of designing and producing new and unthreatened products will go down, resulting in higher incentives for the firms to innovate. Our results regarding import competition from low-income countries indicate a rather weak association with the number of products and a negative association with R&D inputs (expenditures and employees). The former findings might indicate—in line with Bloom et al. (2016), that firms try develop and/or introduce new products to escape low-price competition, but the latter imply rather cost cutting. Reasons for the deviation of our results from Bloom et al. (2016) might be (i) differences in the outcome variable of interest, (ii) differences in the specification of the estimation approach, (iii) that Bloom et al. (2016) rely on a sub-sample of firms (due to systematic differences in the firms reporting R&D in the BvD-Amadeus data), and (iv) that the authors use China's share in the total imports of an industry to proxy competition instead of the domestic market penetration by Chinese firms as we do in this paper (Campbell and Mau 2019).

Our empirical results relate also to Autor et al. (2017), who find, also in a long-term differences specification, that (low-wage) Chinese import penetration is associated with a reduction in R&D and patenting (and sales and employment) for publicly-traded companies in Compustat North America. Our results on the effects of import competition from middle- and low-countries on R&D inputs (expenditures and employment) parallel these findings, but the results regarding the number of products point in the opposite direction. Neither of these studies, however, takes into account difference in the innovation potential of products and look at the effects of import competition from different types of countries.

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 firm-specific strength of import competition. Section three describes our econometric strategy to assess the impact of import competition. Section four presents the results of the econometric analysis of the effects of competition. Section five summarizes and concludes with some discussion.

2. Data and measuring import competition

2.1 Firm data

We use publically available administrative yearly (unbalanced) 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 R&D expenditures, R&D employment and number of actually produced final products (not resale goods) of firms as well as a variety of further firm characteristics. Although, in principle, *AFiD* comprise of the universe of manufacturing firms with at least 20 employees, in the further analysis we use a subsample, because selected variables are collected only for a subsample of about 40% of the targeted population, which rotates every 4 or 5 years. Yet, 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*.

AFiD also provide detailed product level information that allows us to calculate the share of each of the final products (not resale goods) of each firm at the nine-digit-level of the *PRODCOM* classification in firms total output. This information allows us to take firm heterogeneity explicitly into account and 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 firm-specific output markets rather than within broadly defined industries and also allows us to disentangle the effect of final product competition from further influences, if for instance import competition is measured industry-wide and the imports of a certain industry are final output for some firms in that industry and inputs for other firms in the same industry.

Information on patent applications by firms are not contained in the AFiD data, but taken from PATSTAT. The number of patent applications by firm has been merged in a two-step approach. In a first step, we merge to the patent applications from PATSTAT the official and unique business register number of each

applicant from BvD Amadeus, by applying record linkage techniques based on applicant exact name and location. In total, ca. 85% of the patent applicants in PATSTAT could be assigned a business register number. As the business register number is also contained in the AFiD data, patent information and firm-level data can be exactly merged in the second step.

2.2 Measuring import competition

We measure the firm-specific strength of import competition by combining *AFiD* information on the products firms actually produce (not resale goods) 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 measure the firm-specific import competition strength as the share of imports in the total domestic production of goods actually produced by each individual firm

$$(1) \qquad \boldsymbol{IC_{it}^{n}} = \sum_{g} \left[\left(\frac{\boldsymbol{R_{igt}}}{\sum_{g} \boldsymbol{R_{igt}}} \right) \left(\frac{\boldsymbol{M_{gt}^{n}}}{\boldsymbol{M_{gt}^{World}} + \sum_{i} \boldsymbol{R_{igt}}} \right) \right] * \mathbf{100},$$

where g, i, and t indicate the product, firm, and time dimension. R_{igt} and $\sum_g R_{igt}$ are a firm's sales with product g and total sales, respectively. $\sum_i R_{igt}$ denotes the value of the total production of product g.[1] M_{gt}^{n} is the value of the total 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,

[1] It is unclear whether the strength of competition should be measured as the share of imports in the total production of domestic firms or as a share in the domestically consumed production (i.e., subtracting exports). Either way, the strength of competition for some firms might be under-/over-estimated, which might introduce a (between-firm) bias of unknown magnitude because the data do not contain information on exports at the firm-product level and the sizes of both the domestic and the foreign markets of a firm are unknown. However, using national accounts information on exports aggregated at higher product-level (i.e., as of the standard hierarchical classification) will come at the expense of blurring the firm-specific measure of import competition and, therefore, a measurement error. Most importantly, however, for the identification of the effects of competition we use only within-firm variation and the results should be largely unaffected by potential issues due to between-firm mismeasurement and biases.

South Africa, Argentina, Chile, Mexico, Malaysia, Turkey, Thailand, Tunisia, Bangladesh, Indonesia, Philippines, Vietnam and Pakistan (cf., next section 3 for further details and discussion). M_{gt}^{World} is the value to total imports of product g. As mentioned above, using only goods actually produced by each individual firm (not resale goods) ensures that our measure captures only the effects of competition, but not the effects of further channels such as access to better inputs and/or embodied technologies if, for instance, competition is measured at the industry-level and the imports of an industry are final output for some firms in that industry and inputs for other firms in the same industry (Young 1991; Kasahara and Rodrigue 2008; Lileeva and Trefler 2010; Goldberg et al. 2010; Halpern et al. 2015; Ahn and Duval 2017).[2]

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 from differences in the types of goods and products imported from different countries (e.g., characteristics, technology intensity and innovation potential), which imply differences in the type of competition they impose on domestic firms and differences in the 'abilities' of the latter to cope with it. 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 relatively labor-intensive, technologically less sophisticated, have lower unit costs of production and lower quality (Schott 2004; Hummels and Klenow 2005; Khandelwal 2010; Amiti and Khandelwal 2013; Cali et al. 2016).

[2] Using only goods actually produced by a firm ensures that the imports of intermediate inputs do not confound the competition measure. Similarly, our competition measure is not confounded by outsourcing since firms outsource (arguably) the entire production of a good, resulting in a zero share in the product portfolio.

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 domestic production of the goods actually produced (not resale goods) by 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 1 shows some characteristics of domestic firms that are predominantly exposed to imports from high-income countries and of domestic firms that are predominantly exposed to imports from low- and middle-income countries, from which one could infer the characteristics of the imports from the two types of countries.[3] The data do not contain explicit information about the factor and technology content of imported (and domestically produced) goods, yet, we believe that this approach, though not perfect, is a reasonable approximation. Indeed, in line with previous research, mentioned in the paragraph above, 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 mainly from high-income countries are on

[3] See the notes in Table 1 for definition of firms predominantly exposed to imports from high-income/middle- and low-income countries.

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).

3. Identifying the effects of import competition

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

$$R\&D_{it} = \boldsymbol{IC}_{it-1}^{n}\beta^{n} + \boldsymbol{C}_{it-1}'\gamma + \vartheta_t + \theta_{ij} + \varepsilon_{it}, \quad (2)$$

where ω_{it} is firm R&D (expenditures, employees or number of actually produced, not resale goods). $\boldsymbol{IC}_{it-1}^{n}$ is import competition from high-income or from middle- and low-income countries, $n = (High, Low)$, as of (1), lagged by one period as it might take some time for firm to react; it helps also reduce some basic simultaneity issues. As both, competition from high-income countries and competition from middle- and low-income countries are jointly included while the sample of firms is the same, we are able to directly compare their effects and make inference for the average firm in the sample. $\boldsymbol{C}_{it-1}'$ is a set of controls depending on the LHS variable: 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 possibility firms might switch industry and technologies. Thus, we use only within-firm variation to identify the effect of import competition on firms R&D and innovation activities. We apply (inverse probability) weight to ensure representativeness (cf., section 2.1).

We estimate (2) by OLS and by IV-2SLS approach that gives us more confidence drawing causal inference. For instance, the share of foreign firms might particularly large at markets where domestic firms are at disadvantage and have low incentives to invest in R&D and innovation. (Laggard) Domestic firms with little chances to withstand competition might even withdraw or even exit such markets. Depending on the assumptions (e.g., timing, strategic behavior, anticipation, etc.) one is willing to make, the OLS estimates might be downward biased, even though import competition is lagged by one period and unobserved firm-specific time-invariant heterogeneity is accounted for.

In our IV-2SLS strategy, we make use of the idea that the genuine competitiveness of the domestic imports from a country-group *n* will likely be reflected in the share of that country-group in the imports of *third* countries (i.e., besides Germany), which is (arguably) unrelated to the competitiveness and innovativeness of the domestic firms (Autor et al. 2013; Dauth et al. 2014). Thus, we instrument the domestic import competition measures defined in (1) with the share of country-group n in *third* countries' total imports

$$(3) \qquad IS_{it}^{n\to third} = \sum_g \left[\left(\frac{R_{igt=0}}{\sum_g R_{igt=0}} \right) \left(\frac{M_{igt}^{n\to third}}{M_{igt}^{World\to third}} \right) \right] * 100,$$

where $M_{gt}^{n\to third}$ is the value of *third* countries' imports of product(s) g from country-group *n*, $M_{gt}^{World\to third}$ is the value of *third* countries' total imports of product(s) g, and $R_{igt=0}/\sum_g R_{igt=0}$ is product's g share in the total sales of each individual domestic firm, which ensures that only products are considered, which are actually produced by the respective firm.

A necessary condition for our IV-2SLS strategy to identify the effect of import competition is that the instrument as of (3) captures only changes in the domestic share of foreign firms in (1), which are neither directly nor indirectly related to the

R&D and innovation incentives/activities of domestic firms active on the respective markets. However, there might still be some threats to that strategy, which are related to either of the two terms in round brackets in (3). For instance, despite the fact that we use the competitiveness of a country- group n 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, R&D 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 $R\&D_{it}$.

Thus, to minimize the possibility of a correlation between instrument and dependent variable, we reduce the set of countries included in both country-groups, n, and in the set 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.[4] 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. 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. Moreover, we use variation within firm (i.e., over time) in our identification and the exclusion of certain countries should not affect the mechanisms driving the effects of import competition from high-income countries and from low-income countries. With

[4] 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.

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 in (3), $R_{igt=0}/\sum_g R_{igt=0}$, could potentially be itself a threat to the exogeneity of the instrument if firms adjust their product portfolio in reaction to and/or in anticipation of import competition (Bernard et al. 2006; Eckel and Neary 2010). To avoid this, our instrument is based on the constant product portfolio from the first year, $t = 0$, 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 does not change over time, within-firm variation (i.e., over time) in this alternative instrument definition comes entirely from changes in the genuine competitiveness of the trade partners.

4. Results

This section presents the results of the analysis of the impact of import competition on firms R&D and innovation activities. In general, we estimate different specifications of (2) by OLS and IV-2SLS. However, since OLS might suffer from an endogeneity problem (cf., previous section 3 for discussion), we base our interpretations on the IV-2SLS-results.

Table 2 presents the results for the relationship between import competition and R&D expenditures (Panel A), R&D employment (Panel B), the number of products (Panel C), and number of patents (Panel D). According to the estimates in column (4), there seems a positive (yet statistically insignificant) association between import competition from high-income countries, IC_{it-1}^{High}, and R&D expenditures (Panel A) and R&D employment (Panel B). On the opposite, the association between import competition from middle- and low-income countries, IC_{it-1}^{Low}, and R&D expenditures tends to be negative (but statistically insignificant), and negative (and statistically significant) in the case of R&D employment (cf. column (4)). Regarding the number of products (Panel C), there is a positive and statistically significant association with both, import competition from high-income countries and import competition from middle- and low-income countries;

in the former case, however, the association is an order of magnitude stronger (cf., column (4)). Regarding patents (Panel D), we find negative estimates for the effects of both, import competition from high-income countries, IC_{it-1}^{High}, and import competition from low-income countries, IC_{it-1}^{Low}, which are, however, virtually zero in terms of magnitude and statistically insignificant. For all output variables, the estimates for the effect of import competition in general, $IC_{it-1}^{High+Low}$, in column (3) are a combination or two opposite effects and turn out less conclusive, indicating that it is indeed important to distinguish between import competition from high-income countries and import competition from middle- and low-income countries. The OLS estimates in columns (1) and (2) are indeed consistent with a downward bias if import penetration is particularly pronounced in markets where domestic firms are less competitive and have lower incentives to do costly investment in R&D and innovation.

Table 2: Import competition and firm R&D expenditures, R&D employment, and number of products

	(1)	(2)	(3)	(4)
	OLS	OLS	IV-2SLS (2nd stage)	IV-2SLS (2nd stage)
	Panel A: R&D expenditures, in €			
$IC_{it-1}^{High+Low}$	-31,427		190,021	
	(22,646)		(159,191)	
IC_{it-1}^{High}		-18,836		241,312
		(51,011)		(482,464)
IC_{it-1}^{Low}		-35,624*		-109,175
		(18,992)		(69,298)
Observations	78,414	78,414	73,212	73,212
Number of firms	16,925	16,925	15,853	15,853
R^2	0.943	0.943	0.945	0.944
First-stage F-test			55.17	13.13
	Panel B: R&D employment, log (full time equivalents)			
$IC_{it-1}^{High+Low}$	-0.148		0.067	
	(0.124)		(0.230)	
IC_{it-1}^{High}		-0.233		2.223
		(0.346)		(1.962)
IC_{it-1}^{Low}		-0.120*		-0.307**
		(0.062)		(0.136)
Observations	78,414	78,414	73,212	73,212
Number of firms	16,925	16,925	15,853	15,853
R^2	0.970	0.970	0.988	0.988
First-stage F-test			55.17	13.13
	Panel C: Number of products			
$IC_{it-1}^{High+Low}$	0.005		0.023***	
	(0.004)		(0.008)	
IC_{it-1}^{High}		0.003		0.085**
		(0.011)		(0.040)
IC_{it-1}^{Low}		0.006**		0.008*
		(0.002)		(0.005)
Observations	78,414	78,414	78,414	78,414
Number of firms	16,925	16,925	16,925	16,925
R^2	0.974	0.974	0.974	0.974
First-stage F-test			142.1	36.81
	Panel D: Number of patents (ln)			
$IC_{it-1}^{High+Low}$	-0.019**		-0.003	
	(0.008)		(0.059)	
IC_{it-1}^{High}		-0.002		-0.005
		(0.017)		(0.105)
IC_{it-1}^{Low}		-0.023***		-0.002
		(0.008)		(0.055)
Observations	3,174	3,174	2,488	2,488
Number of firms	793	793	764	764
R^2	0.757	0.758	0.750	0.750

First-stage F-test	9.363	7.334

Note: This table reports results from estimating equation (2) by OLS and by IV-2SLS (2nd stage). Import competition is defined as in (1) and in logs. 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 (3). 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). In all regressions included firm-level controls are: firm*industry fixed effects, time fixed effects, export intensity (exports over sales) and number of products (except in Panel C). In columns (3) and (4) instruments are constructed according to (3) using constant product portfolio composition from the first year a firm is observed in the data. Significance: *10 percent, **5 percent, ***1 percent.

5. Summary, discussion and conclusions

In this paper we analyze the impact import competition on (within-)firm R&D and innovation activities. We use comprehensive administrative firm-level panel data from German manufacturing for the period 2000-2014, which contain information on the final products that individual firms actually produce (not resale goods). Combining this information with product-level import information allows us to 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 channels if the industry imports are final products for some firms but intermediates for other firms in the same industry. We assess the effects of import competition on firm R&D and innovation 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.

We find evidence for a differential impact on firm R&D and innovation activities from import competition from low-income countries and from high-income countries. Import competition from industrialized, high-income countries tends to be positively (not always statistically significant) associated with R&D inputs (R&D expenditures and R&D employment) by domestic firms, whereas import competition from middle- and low-income countries tends to be negatively (not always statistically significant) associated with R&D inputs by domestic firms. Moreover, there tends to be a positive (not always statistically significant) association between import competition from either type of countries and the number of products firms actually produce. However, there is little evidence fot effects of import competition on the number of patents.

Overall, we attribute our findings to differences in the characteristics (i.e., R&D/technological intensity) and the innovation potential of the impacted products from different countries and differences in the type of competition. Such differences determine the relative competitiveness gap between foreign and domestic firms and the incentives of the latter to invest in R&D and innovation. In particular, we provide evidence that imports from low-income countries are typically relatively simple, non-differentiable, with lower innovation potential 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, there is rather weak evidence for a product diversification in order to escape competition as indicated by the rather marginal increase in the number of products and low/negative (although not always statistically significant) incentives for the affected firms to invest in costly R&D and innovation as the low innovation potential can’t compensate the price disadvantages, which points to rather cost cutting. Imports from industrialized, high-income countries are, on the opposite, typically relatively capital- and knowledge-intensive, high-quality, differentiable products with higher innovation potential, at which also German firms are comparably good. Accordingly, we find indication for rather positive incentives to innovate towards new products in reaction to import competition from high-income countries, accompanied by some increase (statistically not always significant) in R&D inputs. Overall, the results point out that it is important to distinguish between import competition from high-income countries and import competition from middle- and low-income countries.

The findings of this study fit within the broader framework of international economics, raise some further questions. The generally negative effects of import competition from middle- and low-income countries and the generally positive effects of import competition from high-income countries are consistent with a process of structural transformation and reallocation of resources according to relative comparative advantages (Bernard et al. 2007; Melitz 2003). Yet, we find no evidence that firms try to focus on their main competencies and become more ‘learner’ (Bernard et al. 2007, 2010, 2011; Nocke and Yeaple 2014; Eckel and Neary 2010). Finally, the not always statistically significant estimates might indicate heterogeneity in firm reactions, which is worth detailed examination since relevant for policy.

References

Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P. 2005. Competition and innovation: An inverted-U relationship. *Quarterly Journal of Economics* 120(2), 701-728.

Aghion, P., Blundell, R., Griffith, R., Howitt, P., Prantl, S. 2004. Entry and productivity growth: Evidence from microlevel panel data. *Journal of the European Economic Association* 2(2/3), 265-276.

Aghion, P., Blundell, R., Griffith, R., Howitt, P., Prantl, S. 2009. The effects of entry on incumbent innovation and productivity. *Review of Economics and Statistics* 91(1), 20-32.

Ahn, J., Duval, R. 2017. Trading China: Productivity gains, job losses. *Economics Letters* 160(), 38-42.

Amiti, M., Khandelwal, A. K. 2013. Import competition and quality upgrading. *Review of Economics and Statistics* 95(2), 476-490.

Autor, D. H., Dorn, D., Hanson, G. H. 2013. The China syndrome: Local labor market effects of import competition in the United States. *American Economic Review* 103(6), 2121-2168.

Autor, D., Dorn, D., Hanson, G. H., Pisano, G., Shu, P. 2017. *Foreign competition and domestic innovation: Evidence from U.S. patents*. NBER WP 22879.

Bernard, A. B., Jensen, J. B., Schott, P. K. 2006. Survival of the best fit: Exposure to low-wage countries and the (uneven) growth of U.S. manufacturing plants. *Journal of International Economics* 68(1), 219-237.

Bernard, A. B., Redding, S. J., Schott, P. K. 2007. Comparative advantage and heterogeneous firms. *Review of Economic Studies* 74(1), 31-66.

Bernard, A. B., Redding, S. J., Schott, P. K. 2010. Multi-product firms and product switching. *American Economic Review* 100(1), 70-97.

Bernard, A. B., Redding, S. J., Schott, P. K. 2011. Multi-product firms and trade liberalization. *Quarterly Journal of Economics* 126(3), 1271-1318.

Bloom, N., Draca, M., Van Reenen, J. 2016. Trade induced technical change? The impact of Chinese imports on innovation, IT and productivity. *Review of Economic Studies* 83(1), 87-117.

Bloom, N., Propper, C., Seiler, S., Van Reenen, J. 2015. The impact of competition on management quality: Evidence from public hospitals. *Review of Economic Studies* 82(2), 457-489.

Bloom, N., Romer, P. M., Terry, S. J., Van Reenen, J. 2013. A trapped factors model of innovation. *American Economic Review Papers and Proceedings* 103(3), 208-213.

Bloom, N., Romer, P. M., Terry, S. J., Van Reenen, J. 2019. *Trapped factors and China's impact on global growth*. http://people.bu.edu/stephent/files/TF_MAIN_DOC.pdf.

Campbell, D., L., Mau, K. 2019. *Trade induced technological change: Did Chinese competition increase innovation in Europe*? CEFIR/NES Working Paper No 252.

Cali, M., Francois, J., Hollweg, C. H., Manchin, M., Oberdabernig, D. A., Rojas-Romagosa, H., Rubinova, S., Tomberger, P. 2016. *The Labor Content of Exports Database*. World Bank Policy Research Working Paper 7615.

Clerides, S. K., Lach, S., Tybout, J. R. 1998. Is learning by exporting important? Micro-dynamic evidence from Colombia, Mexico, and Morocco. *Quarterly Journal of Economics* 113(3), 903-947.

Dauth, W., Findeisen, S., Suedekum, J. 2014. The rise of the East and the Far East: German labor markets and trade integration. *Journal of the European Economic Association* 12(6), 1643-1675.

De Loecker, J. 2013. Detecting learning by exporting. *American Economic Journal: Microeconomics* 5(3), 1-21.

Eckel, C., Neary, J. P. 2010. Multi-product firms and flexible manufacturing in the global economy. *Review of Economic Studies* 77(1), 188-217.

Goldberg, P. K., Khandelwal, A. K., Pavcnik, N., Topalova, P. 2010. Imported intermediate inputs and domestic product growth: Evidence from India. Quarterly Journal of Economics 125(4), 1727-1767.

Halpern, L., Koren, M., Szeidl, A. 2015. Imported inputs and productivity. *American Economic Review* 105(12), 3660-3703.

Holmes, T. J., Schmitz Jr, J. A. 2010. Competition and productivity: A review of evidence. *Annual Review of Economics* 2(1), 619-642.

Hummels, D., Klenow, P. J. 2005. The variety and quality of a nation's exports. *American Economic Review* 95(3), 704-723.

Kasahara, H., Rodriguue, J. 2008. Does the use of imported intermediates increase productivity? Plant-level evidence. *Journal of Development Economics* 87(1), 106-118.

Khandelwal, A. 2010. The long and short (of) quality ladders. *Review of Economic Studies* 77(4), 1450-1476.

Lileeva, A., Trefler, D. 2010. Improved access to foreign markets raises plant-level productivity. For some plants. *Quarterly Journal of Economics* 125(3), 1051-1099.

Melitz, M. J. 2003. The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica* 71(6), 1695-1725.

Nocke, V., Yeaple, S. 2014: Globalization and multiproduct firms. *International Economic Review* 55(4), 993-1018.

Schmidt, K. M. 1997. Managerial incentives and product market competition. *Review of Economic Studies* 64(2), 191-213.

Schott, P. K. 2004. Across-product versus within-product specialization in international trade. *Quarterly Journal of Economics* 119(2), 647-678.

Shu, P., Steinwender, C. 2019. The impact of trade liberalization on firm productivity and innovation. *Innovation Policy and the Economy* 19(1), 39-68.

United Nations Statistics Division 2009. *United Nations Comtrade Database*. New York: United Nations. http://comtrade.un.org/.

Van Reenen, J. 2011. Does competition raise productivity through improving management quality? *International Journal of Industrial Organization* 29(3), 306-316.

Young, A. 1991. Learning by doing and the dynamic effects of international trade. *Quarterly Journal of Economics* 106(2), 369-406.