Trade in Services and Innovation

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Abstract

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The effect of an increasing trade integration on the innovation activities of firms has been subject to a growing body of economic research. The overwhelming theoretical and empirical evidence thereby examines the trade-off between an increase in market size and an increase in competition [e.g. Shu and Steinwender (2018), Becker and Peter (2013)]. The fact that trade integration also improves firms’ access to foreign research and innovation received little attention.

Thus, we contribute to the existing literature by examining a new channel of trade integration: trades in innovation services. We develop a theoretical model allowing firms’ to use foreign innovation services as an input to their own innovation activities and test the model’s predictions by using a unique dataset and a newly developed bartik instrument.

The theoretical model is designed to speak directly to the data and is therefore closer to the oligopolistic innovation literature in industrial organization [Spencer & Brander (1983), Bloom et al. (2013)] than to the literature on trade, innovation and growth. We merge two firm-level data sources: 1) the official German Statistics on International Trade in Services and 2) the Mannheim Innovation Panel. This way, we generate the first dataset covering firms’ innovation activities and international purchases of innovation related services. We analyse the causal impact of an increased availability of foreign innovation services on domestic firms’ innovation inputs and outputs by generating a bartik instrument based on the exposure of a firm to foreign trade markets and the foreign markets aggregate development.

Our IV estimates suggest that firms with a higher innovation service (i) undertake more innovation and R&D and (ii) achieve better innovation outcomes. These results confirm our theoretical predictions and suggest that our novel channel of trade integration indeed causally affects firms’ innovation activities. Thus, our findings indicate that the importance of services trades should not be neglected and
discussed in current discussions about new trade agreements.

References


Trade in Services and Innovation

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1 Introduction

International trade integration not only provides firms with greater access to foreign export markets but might also facilitate the spread of knowledge and technology across borders (IMF (2018)). While the effect of trade in goods on firms’ innovation activities has received a considerable amount of attention, much less is known about how international trade affects innovation through facilitating access to foreign knowledge. In this paper, we use trade in innovation-related services as a direct measure of knowledge flows across countries and analyze their effect on firm-level innovation activity.

We assemble a new data set containing information on the international transactions of innovation services, innovation activities as well as exports of German firms. The exceptional level of detail in our data allows us to document and estimate the effects of international market integration on innovation activities that operate through facilitating access to foreign innovation services while accounting for traditional trade channels such as export market size and competition. To guide our empirical analysis, we build a new theoretical model of heterogeneous firms and innovation, trade in innovation services, and trade in goods.

We merge confidential firm-level data from the Deutsche Bundesbank and the ZEW – Leibniz Centre for European Research. This allows us to jointly track firm-level imports and exports of innovation services - primarily in the form of R&D - as well as detailed information regarding their innovation and export activities. Beyond providing information on a firm’s R&D and overall innovation expenditures, the data contains information outcomes associated with innovation activity: reductions in unit cost, increases, and the sales accounted for by improved and new products.

After presenting our data, we begin by documenting salient empirical facts regarding the nature of firm-level innovation activities, trade in innovation services, and exports that guide and motivate our theoretical and empirical analysis. We document that few firms import innovation services. Conditional on doing so, these firms tend to import innovation services every year, which is consistent with imports being subject to both fixed and variable costs. Also, consistent with selection, innovation service importers display higher revenue to labor ratios, pay higher wages, and are more skill-intensive.

Our data indicate that innovation expenditures are a more comprehensive measure of innovation activity than R&D expenditures: R&D expenditures capture less than two-thirds of overall innovation-related expenses. This suggests that measures based on R&D miss a sizeable share of innovation activity. The data is consistent with selection into being an innovator. Further conditional on innovating once, most firms incur costs related to innovation activities every year. Variance decompositions of
aggregate innovation activity further suggest that differences in innovation activity across similar firms are an essential driver of aggregate innovation outcomes. This motivates our focus on studying the determinants of within-industry differences in innovation outcomes across similar firms. Lastly, we document that there is suggestive evidence of selection complementarities between innovating, importing innovation services, and exporting.

To rationalize these reduced-form facts, we develop a model of heterogeneous firms, innovation, and trade in goods and innovation services. In the model, firms devote resources separate from production to innovation activities, which are aimed to improve profitability. The model remains parsimonious as to whether innovation primarily affects demand (product innovation) or costs (process innovation). Incentives to innovate are (endogenously) shaped by profit margins (competition) and by the size of goods markets. Market size scales the benefits of innovation. The efficiency at which firms generate innovation outcomes increases through the integration of foreign innovation services, implying that access to foreign innovation output, through trade in innovation services, allows some firms to gain a competitive advantage in innovation efficiency. Our model of innovation service imports adopts the model developed in Halpern et al. (2015) to our context. Fixed costs to importing foreign innovation services imply that high innovation expenditures, better innovation outcomes, and higher import intensities in foreign innovation services are joint outcomes in the model. Further, our model predicts that access to foreign export markets increases a firm’s innovation expenditures.

To test the core prediction of the model, we investigate the causal effect of heterogeneity in exposure to foreign markets and competition on innovation activities across firms. To account for the joint selection and resulting reverse causality between exporting, importing and innovation, we construct novel firm-level instruments using a shift-share design (Bartik (1991)) familiar from the international trade and labor literature (Garin & Silvero (2018); Lileeva & Trefler (2010)). We leverage intra-industry heterogeneity in firm exposure to international demand and supply shocks to identify the relative effects of access to foreign innovation services, market size, and competition on relative innovation activities of German firms within the same industry.

Our estimates confirm the key predictions of our model and give first direct evidence on the impact of trade in innovation services on firms’ incentives to innovate. We find that firms with relatively better access to foreign innovation services undertake more substantial innovation efforts, as measured by both overall innovation spending and

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1 The model is designed to speak directly to the data and is therefore closer to the oligopolistic innovation literature in industrial organization (Spencer & Brander (1983), Bloom et al. (2013)) than to the literature on trade, innovation and growth (e.g. Grossman & Helpman (1991)).
total R&D spending. We also find that firms with relatively higher exposure to foreign supply shocks to innovation services achieve better innovation outcomes across all our measures relating to product and process innovation. As our core theoretical mechanism postulates that foreign innovation services improve the efficiency at which firms innovate, we interpret these findings as lending direct empirical support to the central predictions of our theoretical framework.

The results further indicate that firms’ incentives to undertake costly innovation activities are positively affected by market size. We find that relatively larger exposure to foreign export markets incentivizes firms to spend more resources on both overall innovation activity and R&D. We find that these efforts translate into better product innovation outcomes - as measured by the revenue generated by new and significantly improved products. However, we cannot detect any statistically significant effects of foreign demand on the incentives to innovate on processes. Our results therefore confirm the positive effect of exports on firms’ incentives to innovate documented found in recent studies (Lim et al. (2018), Aghion et al. (2018), Steinwender (2015)). However, our results indicate that the effects might differ across process and product innovation, as hypothesized in Dhingra (2013).

Our results shed new light on the effects of competition on firm-level innovation incentives. We find that higher competition in product markets disincentivizes firms from innovating, as measured by overall innovation expenditures. This effect is primarily driven by the fact that firms are disincentivized to innovate on production processes. This finding is consistent with the critical mechanism of our model, where innovation incentives, in part, depend on the elasticity of firms’ profit margins with respect to unit cost. In the model, higher levels of competition may reduce the capacity of firms to achieve higher profit margins by increasing their market share. However, we also find that higher levels of competition increase firms’ incentives to invest in R&D and product innovation. This is consistent with recent findings by Fieler & Harrison (2018), who argue that firms may aim to escape higher levels of competition by introducing new products.

**Literature**  Our study is related to a large and growing literature on the inter-linkages of trade and innovation, and in particular, to Steinwender (2015), Aghion et al. (2018), Fieler & Harrison (2018) and Lim et al. (2018), all of which study the effect of trade in goods on firm-level innovation activity. Shu & Steinwender (2019) provide a comprehensive overview of the empirical literature, which the interested reader is referred to. Relative to the existing empirical literature, we make two contributions. Firstly, we provide the first causal evidence on the impact of trade in services on firm-level innovation activity. Further, we investigate innovation activities from many angles,
thanks to the comprehensive nature of our data.

Our paper further relates to a small but growing literature on the effect of trade in services on aggregate and firm-level outcomes. As data and reliable measurement of firm-level trade in services have only recently become available, previous studies are mainly concerned with establishing empirical and conceptual differences between trade in goods and trade in services (e.g., Breinlich & Criscuolo (2011), Ariu (2016), Ariu et al. (2017), Eaton & Kortum (2018)). Few, in contrast, have related changes in trade cost in services to aggregate outcomes. Two exceptions are Eckert (2019) and Eckert et al. (2019), who argue that changes in trade costs of business services are key to understanding the geographic variation of changes in the skill premium across the US. Relative to this literature, we are the first to study the effect of trade in innovation-related services on innovation activity.

2 Trade in Services

2.1 Measurement

According to the General Agreement on Trade in Services, services trades are classified across four modes:

1. Mode 1 corresponds to classical cross-border supply – a service is provided from the member of territory A to a member of territory B across borders. A French firm based in France providing innovation services for a German firm based in Germany would constitute such an instance.

2. Mode 2 resembles service consumption abroad – a service is provided from the member of territory A to the member of territory B within territory A. An example for such a case would be a French firm based in France providing innovation services to a subsidiary of a German firm located in France would.

3. Mode 3 - commercial presence - captures if a service is provided from the member of territory A to the member of territory B within territory A, for instance, the subsidiary of a French firm providing innovation services to a German firm within Germany.

4. Mode 4 corresponds to services provided through individual persons – a service is provided by a person living in territory A to a firm or person located in territory B. For example a French freelance engineer traveling to Germany to provide innovation services to German firms.
Within these Modes, Modes 1, 2 and 4 are captured by the official trade in service statistics as aggregate. Thus, it is not possible to distinguish between them. Mode 3 is part of the statistics on firms’ multinational activities and FDI. While the data does not allow for further disentanglement, estimates for the US suggest that the vast majority of service trade happens through mode 1 and 3.

2.1.1 An Example of Trade and Barriers to Trade in Innovation Services

Due to the limitation of 10,000 words, the example is only available upon request.

2.1.2 Aggregate Trends in Trade in Services

Trade in services has increased sizeably over the last decades. We use the World Bank’s Trade in Services Database to construct aggregate statistics on world imports of R&D related services. Figure A.1 shows that international flows in R&D services have increased and nearly five-fold between 2000 and 2011. Further, world trade in R&D is outgrowing the overall trade in services. The share of R&D imports in total service imports has increased from one to three percent in the same period.

2.2 Firm Level Data from Germany

We merge three confidential firm-level data sets. In total, our sample contains around 7,200 firms and 18,000 firm-year observations, covering firms active in manufacturing industries between the years 2002 and 2011.

Firm-level service imports  The Statistics on International Trade in Services (SITS) database, described in great detail in Biewen & Lohner (2017), provides information on the service transactions of German firms. Access to the data is provided through the Research and Data and Service Centre (RDSC) of the Deutsche Bundesbank. The database is used to compile Germany’s Balance of Payments Statistics, and thus, each firm must report all service transactions whose joint volume exceeds the amount of 12,500 Euro for a given month, country, and service type. The data, therefore, practically includes all service trades of German firms. For our analysis, we extract the yearly values of firms’ reported service transactions classified according to its service type, its direction, and the involved foreign country. In total, we label four types of service imports as innovation-related: (i) R&D, (ii) patents, licenses, and innovations, (iii) artistic copyrights, and (iv) other rights (such as franchises, trademarks, and

\[ \text{DOI}: 10.12757/Bbb.SITS.0116.01.01. \]
marketing rights). R&D accounts for the bulk of these transactions and is the main focus of our analysis.

**Innovation Data**  The Mannheim Innovation Panel (MIP)\(^3\) is gathered in the form of yearly surveys by the ZEW – Leibniz Centre for European Economic Research and constitutes the German contribution to the European Commission’s Community Innovation Survey. The MIP is our primary source of information on firms’ innovation activities and other firm-level outcomes, such as employment, goods exports, and internal R&D activities.

The data contain information on firms’ expenditures on innovation activities broadly and on R&D in particular. Moreover, it contains data about the introduction of new products, services, and processes and their success. Firms declare whether their innovation activities yielded new or improved products or services, as well as the revenue share that these account for. The data allows us to distinguish further the revenue share of products that are (i) new to the firm, (ii) new to the firm and the market, and (iii) new to the firm without a predecessor product. Related to process innovation, firms state whether they introduced new or significantly improved processes and by how much these process innovations reduced unit costs and raise revenues by improving product quality.

Further, the MIP contains data on other firm characteristics, such as revenues, the volume of exports, total employment, wages, intermediate inputs and internal R&D activities.

**Multinational Activity**  For information on FDI activity in Germany, we access the Microdatabase Direct Investment (MiDi),\(^4\) described in detail in Schild & Walter (2017),\(^5\) which contains information on all inward and outward FDI stock relations that German companies are involved in and considered as economically relevant for aggregate FDI statistics. Access to the data is provided by the Research and Data Services Centre (RSDC) of the Deutsche Bundesbank. A common concern in the trade in services literature is the phenomenon of profit shifting where firms use non-tangible transactions between subsidiaries in different countries to shift taxable income. Thus, to tackle this concern, we use the information stemming from the MiDi to control if a firm in our sample is part of such a connection and can be considered a multinational firm.

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\(^3\) For more information, please see here: https://www.zew.de/en/forschung/mannheim-innovation-panel-innovation-activities-of-german-enterprises/

\(^4\) DOI: 10.12757/Bbk.MiDi.9915.03.04

\(^5\) The data report can be found here.
The merging of the Mannheim Innovation Panel (MIP) with the Trade in Services Statistics (SITS) and the Microdatabase Direct Investment (MiDi) took place at the Research and Data Service Centre (RDSC) of the Deutsche Bundesbank and relied on the mapping tables described in Schild et al. (2017).

3 New Facts on Firm-level Innovation and Trade in Innovation Services

In this section, we present descriptive facts that motivate our approach in the following theoretical and empirical analysis.

3.1 Firm-level innovation activities

Innovation Inputs  Sixty-four percent of firms in our sample are innovators, which we define as firms that have strictly positive innovation expenditures. Table A.2 shows that innovative firms are larger both in terms of revenues and employment, with the average firm spending a total of 4.7 EUR million or around 4 percent of total revenues on innovation activities.

Innovation expenditures are a broader measure of innovation activity than R&D expenditure. Table A.2 shows that R&D expenditures on average account for about two-thirds of total innovation expenditures. Further, only 82 percent of firms that innovate conduct continuous R&D. Average R&D imports of firms with positive innovation expenditures equal 227.000 Euro, which corresponds to 5 percent of average total innovation expenditures.

Innovation Outcomes  Our data is indicative of sizeable differences in both the objectives and outcome measures of innovation activities. While innovative efforts in general aim to improve a firm’s profitability, a firm may target either product innovation – the development of new or the improvement of existing products and services - or process innovation – which affects the unit cost of production or the quality of its products and services.

Table A.2 indicates that 74 percent of innovating firms target product innovation. However, our data shows that the average revenue share of new product varieties only amounts to 11 percent, while 20 percent of revenues occur through adopted

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6 The technical report is available here.
### Table 3.1 Variance Decomposition of Sample Innovation Activity

<table>
<thead>
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<th>Decomposition</th>
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<tbody>
<tr>
<td>Share of Variation Between Sectors</td>
<td>$\frac{\text{Var}(\hat{\alpha}<em>s, t)}{\text{Var}(IE</em>{ft})}$</td>
</tr>
<tr>
<td>Share of Variation Within Sectors</td>
<td>$1 - \frac{\text{Var}(\hat{\alpha}<em>s, t)}{\text{Var}(IE</em>{ft})}$</td>
</tr>
</tbody>
</table>

**Notes:** This table presents a decomposition of the overall sample variance in logged innovation expenditures. Source: Mannheim Innovation Panel (MIP), 2002-2011, own calculations.

Products. In line with this empirical regularity, the baseline version of our theoretical framework solely models product innovation that improves existing varieties.\(^7\)

Conditional on being an innovator, about 50 percent of firms target process innovation. We observe that the average reduction in unit cost amounts to 3 percent, while the average revenue increase resulting from quality improvements equals 2.8 percent.

**Aggregate relevance** How important are firm-level differences in innovation activities for the aggregate, in particular, relative to differences in innovation spending across sectors? To answer this question, we provide a decomposition of the aggregate variation in innovation expenditures into a between-sector and a within-sector component. To do so, we regress innovation expenditures, $IE$, on a set of industry-year fixed effects $\alpha$:

$$IE_{ft} = \alpha_{s,t} + \varepsilon_{ft}, \quad (3.1)$$

where $f$ denotes firms, $t$ denotes years and $\varepsilon_{ft}$ is an error term. The total variance of innovation expenditures decomposes as follows:

$$\text{Var}(IE_{ft}) = \underbrace{\text{Var}(\alpha_{s,t})}_{\text{Between Sectors}} + \underbrace{\text{Var}(\varepsilon_{ft}) + 2\text{Covar}(\alpha_{s,t}, \varepsilon_{ft})}_{\text{Within Sectors}}. \quad (3.2)$$

We estimate the fixed effects (3.1) and decompose the sample variance in innovation expenditures according to equation (3.2) Table 3.1 displays the results and shows that the lion share of the overall sample variation in innovation expenditures stems from within-industry rather than between-industry heterogeneity in innovation activities.

\(^7\) However, our analysis readily extends to the case where innovation may take the form of adding new varieties to the extensive margin.
3.2 Trade in Innovation Services

3.2.1 Few firms import foreign innovation services

As pointed out for other types of services and other countries (Ariu et al. (2017); Breinlich & Criscuolo (2011)), trade in innovation services is similar to trade in goods in that only few firms engage in this activity. Table A.1 displays the composition of firms in our sample. In total, 3 percent of manufacturing firms in our sample import foreign R&D.

3.2.2 Foreign Innovation Services are a Variable Input into Innovation Generation

Importing foreign R&D services does not constitute a one-time event for an individual firm. In our sample, an average of 69 percent of firms that import foreign R&D services in one year will import R&D services also in the next year. For comparison, an average of 88 percent of firms that export in one year will also export in the following year. Consistent with this fact, we model foreign R&D services as a variable input in the production of innovation outcomes.

3.2.3 Innovation Service Imports and Innovation

Importers of innovation services are significantly more active as innovators than the average firm. As shown in Table A.2, R&D service importers outspend the average innovating firm by a factor of five on both total innovation and R&D expenditure. Further, R&D service importers also outspend the average multinational firm by a factor of two on both margins.

These expenditures translate into better innovation outcomes. Table A.2 shows that revenues accounted for by new products equal 23 percent for importers of R&D services, relative to 20 percent across the whole sample of innovators, while the revenue shares accounted for by new products accounts for 14 percent relative to 11 percent for the whole sample.

3.2.4 Selection into Importing R&D services

We assess the conditional correlation between R&D service imports and a simple empirical measure of firm productivity. To do so, we regress firm’s importer status of foreign innovation services in year \( t \) (\( 1_{\text{IMP}_{f,t}} \)) on its empirical revenue labor productivity (\( \text{RLP}_{f,t} \)), which we measure by the ratio of total revenues to total employment. We

\( ^8 \) As highlighted in the later analysis, the results are qualitatively robust to this assumption.
control for the share of workers holding a university degree as a measure of skill intensity, its location (East or West Germany) as well as sector-year fixed effects \( (\alpha_{s(f),t}) \):

\[
1^{\text{IMP}}_{f,t} = \alpha_{s(f),t} + \beta \text{RLP}_{f,t} + \gamma' \text{Controls}_{f,t} + \epsilon_{f,t}.
\]  

(3.3)

Table A.3 displays the results and shows that, consistent with selection into service trade, importers of innovation services have higher measured labor revenue productivity and are more skill-intensive. For reference, the remaining columns of Table A.3 display the results of estimating equation (3.3) with exporter and innovator status as dependent variable.

We interpret the correlations between a firm’s labor revenue productivity and its R&D services importer status as being consistent with firms selecting based on unobserved productivity differences into importing foreign R&D services. Selection is the central mechanism in much of the modern heterogeneous firm literature on trade in goods through which the effects of international trade materialize, and our model of R&D service imports will inherit qualitatively similar features.9

3.3 Complementarities in Selection

Table A.4 displays the joint distribution of firms across their observed trade status. Fifty-four percent of firms that import foreign R&D services are multinationals. Further, 70 percent of firms that import foreign R&D services also export their products to foreign markets. Taken together with the previous facts, we argue that this pattern is consistent with a model where underlying productivity differences across firms drive selection into export, innovation, and import activities.

4 A Model of Foreign Knowledge Imports, Trade and Innovation

We develop a model of trade in goods, R&D services, and innovation in the context of oligopolistic competition in product markets, firm heterogeneity in productivity and selection into exporting, importing R&D, and innovation. The purpose of the model is to understand in which way changes in trade cost of goods and services shape the incentives of firms to undertake costly innovation.

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9 While Bernard & Jensen (1995) were the first to empirically document the importance of firm heterogeneity and selection into trade, Melitz (2003) laid the foundation for most of the subsequent theoretical literature.
4.1 Model Overview

Single-product firms in a home market $H$ - Germany in the application - are associated with an industry $s$ and have the option to purchase external knowledge as an input to their innovation activities and to sell products on domestic and foreign markets, which we denote by $m$. The model is not dynamic. However, to capture the forward-looking nature of innovation activities, we model events across three stages.

In the first stage, firms randomly draw a multi-dimensional vector $\Theta \in \mathbb{R}^n_+$ from a cumulative distribution function $G(\Theta)$. $\Theta$ captures exogenous differences in production efficiency, innovation capacity, product appeal, and fixed cost. Consistent with the suggestive evidence of selection, firms have fixed cost to selling products in foreign or domestic markets as well as to innovating at later stages. Firms make their optimal choice by maximizing their expected profits while anticipating outcomes of the upcoming two stages.

In the second stage, firms choose their innovation efforts and sourcing strategies for foreign innovation services. We assume that innovation efforts do not materialize immediately, but firms foresee their outcome in the third and final stage. This assumption yields the critical optimality condition that relates firms’ incentives to innovate to all relevant channels in our model. As we focus on single product firms, our model does not capture product innovation in the form of adding new products. However, the model readily extends to this case without changing the qualitative results.

Finally, in the last stage, the chosen innovation efforts materialize, and firms compete oligopolistically in the product markets that they chose to enter in the initial stage.

The model, therefore, constitutes a game across three periods. We proceed by describing and simultaneously solving the game through backward induction, starting with describing the structure of demand and final good competition in the third stage.

4.2 Demand and Competition in Goods Markets

To characterize the outcome of product market competition in the final stage, and we drop subscripts for industries $s$ and individual markets $m$. We describe the equilibrium in a given market and industry where a total of $N$ firms, domestic firms that have selected into selling in this market as well as other foreign firms, are active. Individual firms are denoted by $f \in \{1, ..., N\}$.

Following Amiti et al. (2018), we impose assumptions on demand that imply that a

\footnote{While the correlation between draws on those dimensions is key to governing equilibrium patterns of joint selection, none of our results depend on its dimensionality. For most of the paper, it is easiest to think of $\Theta$, as a standard one-dimensional productivity parameter.}
firm’s market share is a sufficient statistic for the demand price elasticity it faces. In particular, we assume that demand is given by an invertible, homothetic demand system that can be written as \( q_f \equiv \log Q_i = q(p_f, \xi_f, \mathcal{A}) \), where \( p_f \equiv (p_f; p_{-f}) \) is the vector of prices of firm \( f \) and all other \( N-1 \) firms active in the same market, and \( \xi_f \equiv (\xi_f, \xi_{-f}) \) is a vector of non-price firm characteristics affecting demand.\(^{11}\) \( \mathcal{A} \) is a vector of aggregate demand shifters that is exogenous from the perspective of active firms.

We characterize the equilibrium in product markets under full-information simultaneous-move price-setting without any restrictions on the nature of competition, which might be monopolistically competitive or oligopolistic competition in prices or quantities. We restate the key properties of the product market equilibrium in this set-up derived by Amiti \textit{et al.} (2018) in the following proposition.

**Proposition 1** (Amiti \textit{et al.} (2018)) Assume that sectoral log expenditures \( z \) are a sufficient statistic for firm’s perceived demand elasticities, \( \sigma_f \equiv \frac{dq_f}{dp_f} = \sigma(p_f - z, \xi_f) \). Then under any competition structure, the equilibrium price of firm \( f \) is a mark-up over marginal cost \( MC_f \) and solves the following fixed point:

\[
p_f = \log \left( \frac{\sigma_f}{\sigma_f - 1} \right) + \log MC_f. \tag{4.1}
\]

Further, changes in market shares \( S_f \equiv \frac{p_f Q_f}{\sum_{i=1}^{N} p_i Q_i} \) are a sufficient statistic for equilibrium changes in mark-ups:

\[
d \log \left( \frac{\sigma_f}{\sigma_f - 1} \right) = \Omega(S_f) d \log S_f. \tag{4.2}
\]

In equilibrium, marginal cost depend on the innovation effort that a firm has undertaken at the second stages of the game. Under the assumption that the log expenditure function summarizes all necessary information contained in competitor prices, Proposition 1 implies that market shares are a sufficient statistic for the level as well as for changes in firms’ mark-ups.\(^{12}\) Mark-ups, in turn, govern how profit margins shape innovation incentives: If high market-shares imply high mark-ups and, therefore profit margins, then firms will be more willing to undertake costly innovation activities that improve their competitiveness, market shares and thus profit margins.

In summary, the characterization of the final goods market competition nests many existing frameworks, and in particular, Atkeson \& Burstein (2008). Hence, the results

\(^{11}\) All results extend straightforwardly to the case where \( \xi_f \) is a function of firm innovation effort.

\(^{12}\) This assumption holds exactly for the nested-CES demand structure commonly used in models of oligopolistic competition (in particular Atkeson \& Burstein (2008)), but also more broadly to a first order for Kimball Kimball (1995) demand or the broad homothetic family of demand considered in Matsuyama \& Ushchev (2017).
derived in the upcoming sections apply to a broad set of models that study the implications of market power and imperfect competition in product markets.

4.3 Innovation Decision and Import of Foreign Innovation Services

In the second stage, firms have incurred fixed costs to serve markets and to set up their capacity to innovate. Firms that did not choose to set up innovative capacity move on to the next stage. All other firms simultaneously choose the optimal amount of innovation $x_f$ non-strategically and without spillovers. Firms also choose their sourcing strategy for foreign innovation services, which affects the cost of innovation $\Gamma_f(x)$. Firms foresee the outcome of the product market competition in the final period. Therefore, a firm with access to a set of markets $M_f$, and unit cost of serving market $m$ given by $C_{m,f}$ chooses innovation intensity $x_f$ to maximize profits according to:

$$\Pi(x_f; \Theta_f) = \sum_{m \in M} \left( P_{m,f} Q_{m,f}(x_f; \Theta_f) - C_{m,f}(x_f; \Theta_f) Q_{m,f}(x_f; \Theta_f) \right) - \Gamma_f(x_f, \theta_f), \quad (4.3)$$

subject to the outcome of the product market game summarized by the optimal pricing decision in equation (4.1). Note that innovation might affect both product demand and the unit cost of production. We assume that production functions are constant returns to scale for any given innovation effort $x$.

**Assumption 1**

1. Production functions are constant returns to scale for any level of innovation effort $x$.
2. Product demand is weakly increasing and concave, while unit cost are weakly decreasing and concave in innovation effort $x$.

We further assume that shipping goods to market $m$ is subject to iceberg trade cost, which are denoted by $\tau_m \geq 1$. **Assumption 1** implies that the unit cost $C_{m,f}$ of producing a unit of output for market $m$ equal marginal cost, adjusted for trade cost: $C_{m,f} = MC_{m,f} = \tau_m C_f$. By the envelope theorem, the optimal amount of innovation effort $x_f$ solves the following first-order condition:

$$\sum_{m \in M} \left( \frac{1}{\sigma_{m,f}} - 1 \right) C_{m,f} \frac{\partial Q_{m,f}}{\partial x_f} - \frac{\partial C_m}{\partial x_f} Q_f = \frac{\partial \Gamma_f(x_f, \Theta_f)}{\partial x_f}, \quad (4.4)$$

where $Q_f \equiv \sum_{f \in M} \tau_f Q_{m,f}$ denotes total production of firm $f$.

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13 For our purpose, it is inconsequential whether innovation yields certain or probabilistic outcomes, so long as firms hold common expectations about the effects of innovation. We, therefore, characterize the full information case.
It is worth pausing to discuss how this simple condition relates to the channels affecting firms’ incentives to innovate. Focusing on the first term, we observe that both high unit costs $C_f$ and profit margins $\frac{1}{\sigma_{m f} - 1}$ will *ceteris paribus* give rise to larger innovation spending. The second term, on the other hand, summarizes the returns to process innovation. The returns to process innovation - summarized in the reduction in unit cost $\frac{\partial C_{m f}}{\partial x_f}$ - are scaled by a firm's total output $Q_m$. Lastly, the impact of foreign innovation services on innovation materializes through the marginal cost of innovation, which is firm-specific and depends on the sourcing strategy of foreign R&D, which firms choose simultaneously with their innovation intensity. As we will show next, lower trade cost in services reduce the marginal cost of innovating, and by more so for firms with higher import intensities.

**Production of Innovation and Innovation Cost** Firms produce innovation $x$ by combining factors $F$, and intermediate inputs $M$ according to a Cobb-Douglas production function:

$$x_f = \chi\left(\Theta_f\right) M^{\phi} F^{1-\phi}. \quad (4.5)$$

$\chi\left(\Theta_f\right)$ governs firm heterogeneity in innovation efficiency. The factor $F$ can be purchased at a common, exogenous price $W$.

We model foreign sourcing decisions by generalizing the setup in Halpern et al. (2015) to many potential sourcing countries. Intermediate inputs in innovation production consist of a bundle of innovation services indexed by $j \in [0, 1]$ - for example, basic research or product testing - and are aggregated according to Cobb-Douglas technology:

$$M_f = \exp\left\{\int_0^1 \alpha_j \log X_{f,j} dj\right\}. \quad (4.6)$$

The types of innovation services vary in their importance, measured by a weight $\alpha_j$, where $\int_0^1 \alpha_j dj = 1$.

Each innovation service can be either produced at home or imported from market $m \in M$. Home and foreign innovation inputs are combined to yield an innovation service input through to the following CES aggregator:

$$X_{f,j} = \left[Z_{f,j}^{\frac{1}{\kappa}} + \sum_{m \in M} a_{m,j}^{\frac{1}{\kappa}} M_{f,j,m}^{\frac{1}{\kappa}}\right]^{\frac{\kappa}{\kappa-1}}, \quad (4.7)$$

where $Z_{f,j}$ and $M_{f,j,m}$ respectively denote the quantities of domestic and imported varieties from source country $m$. $a_{j,m}$ is a measure of technological advantage that
foreign services may have over domestic ones. Note that the CES aggregation implies that the firm does not need to use foreign intermediates. However, because of the love-for-variety property of the CES as well as potential technological advantages \( a_{m,f} \), the inclusion of foreign innovation services can be advantageous in terms of innovation output.

Firms pay fixed cost \( f_m \) in units of the domestic aggregate factor of production for each foreign innovation input that they wish to import from country \( m \). Also, firms pay variable trade cost \( \tau_{R&D,m} \) on top of the foreign price \( U_{j,m} \). The domestic price of innovation activity \( j \) is denoted by \( V_j \).

To derive innovation cost, we assume that firms have chosen the set of varieties that they wish to import, \( J_f = \{ j \in [0,1], m \in M : M_{f,j,m} > 0 \} \), and are left with choosing the quantities \( M_{f,j,m}^*, Z_{f,j}^* \) and \( F_f^* \). The total cost of generating innovation, evaluated at optimal quantities denoted by asterisks, are then given by:

\[
\Gamma(x_f|J_f^*) = WF^* + \int_0^1 V_f Z_f^* dj + \sum_{m \in M} \int_{J_f^*} \left( \tau_{R&D,m} M_{f,j,m}^* + W_{f,m} \right) dj.
\]

(4.8)

In Appendix B.1, we show that the variable part of total innovation cost, conditional on a set of imported varieties \( J_f^* \) is given by:

\[
\Gamma(x_f|J_f^*) = \frac{C}{B_f^\phi \chi(\Theta_f)} x_f,
\]

(4.9)

\( C \) is a cost-index for firms that do not import innovation services as part of their innovation activities.\(^{14} \) \( B_f \) is a cost-reduction factor that summarizes how foreign innovation services improve the efficiency at which a firm produces innovation activities: \( B_f = B(J_f) = \exp \left\{ \int J_f \alpha_j \log b_j(J_m) \, dj \right\} \) where \( b_j(J_m) \equiv \left[ 1 + \sum_{\{j,m\} \in J_f} a_{j,m} \left( \tau_{R&D,m} U_{j,m} / V_j \right) \right]^{1/\zeta} \).

Thus, importing foreign technology services affects the efficiency at which firms produce innovation output though the term \( B_f \). Within the model, gains from trade in services arise as they allow domestic firms to achieve innovation outcomes at lower cost.

One main goal of our model is to characterize the determinants that govern heterogeneity in innovation responses to a change in the trade cost of foreign innovation services across firms. The import intensity in foreign innovation services from country \( m \), defined as the share of expenditures on innovation services from country \( m \) in total

\(^{14} \) This index is given by: \( C = \left( \frac{U}{\phi} \right) \left( \frac{W}{1-\phi} \right)^{1-\phi} \) with \( U \equiv \int_0^1 \alpha_j \log \left( \frac{U_j}{\eta} \right) \, dj. \)
The variable cost of innovation, is a key statistic for this purpose and defined as follows:

\[
ρ_{f,m} = \frac{\int \tau_m U_{j,m} M_{j,m}^* dx_j}{\Gamma(x_J)} = \phi \int_0^{J_f} \alpha_j a_{j,m} \left( \frac{\tau_{R&D} U_j}{V_j} \right)^{\kappa_j} dj.
\] (4.10)

The following proposition relates overall import shares of foreign innovation services to the variable and marginal cost of innovation. Further, it shows that \(φ_i\) is a sufficient firm-level statistic to characterize changes in the marginal costs of innovation due to changes in trade costs in services, \(τ_{R&D}\).

**Proposition 2** (i) Within sectors firms with larger total innovation expenditures have a larger overall import intensity \(φ_f \equiv \sum_m ρ_{f,m}\). (ii) The partial elasticity of marginal innovation cost with respect changes in the variable trade cost of foreign innovation services \(τ_{R&D}\) equals \(\frac{∂ \log Γ'(x_f)}{∂ \log τ_{R&D}} = ρ_{f,m}\) if the set of imported varieties is fixed and \(\frac{∂ \log Γ'(x_f)}{∂ \log τ_{R&D}} = κ ρ_{f,m}\) to a first order if the set of imported varieties adjusts as well. \(κ\) is a constant specified in the appendix.

**Proof.** See Appendix B.1.

Proposition 2 highlights that the model provides a direct link between the import intensity of foreign innovation services, changes in service trade costs and firm-level innovation efforts: From (ii), we know that the elasticity of marginal innovation cost with respect to the costs of service trade is increasing in a firm’s exposure to imported innovation services. Changes in trade costs, thus, have a larger effect on the total innovation costs of firms with higher import shares. Moreover, from (i), we also know that firms with higher import intensities also have larger total innovation expenditure. Therefore, reductions to trade cost in services, for instance, pose disproportional high benefits for firms with larger total innovation expenditure.\(^{15}\)

### 4.4 Selection and Entry

In the first stage, an exogenous number of firms \(M\) each choose which subset \(M_f\) of the markets \(\{H, M\}\) to enter and whether or not to build the capacity to innovate, \(1_i\). The associated fixed costs, \(F^E_H, F^E_m\) and \(F^I\), respectively, are produced by an aggregate factor with price normalized to 1. Firms also choose the set of innovation services \(J_f\) that they would like to import by anticipating the outcomes of the second and third stages of the game.

\(^{15}\)The implications for fixed costs are simple and in particular first-order invariant across firms: The partial elasticity of marginal innovation cost with respect to a change in fixed cost is given by: equal to some constant: \(\frac{∂ \log Γ'(x_f)}{∂ \log τ_{m}} = κ_1\).
The problem of each potential entrant in the first stage reads:

$$\max_{M_f, J_f, \theta_f} \Pi(M_f, J_f, \theta_f) - \sum_{m \in M_f} 1 \{m \in M_f\} F^E - 1_{I, F^I}, \quad (4.11)$$

where $\Pi$ denotes profits accrued in the later stages.

As a last step, we characterize $J_f$, the set of imported innovation service varieties. Firms foresee outcomes at later stages of the game, and hence the envelope theorem implies that firms choose their set of imported innovation services $J$ to minimize their expected total cost of innovation.

$$J^*_f = \arg \min_{J_f} \mathbb{E} \left( \Gamma(x_f | J_f) \right) = \mathbb{E} \left( \frac{C}{B^\theta x_f} - W \sum_{j \in J_f} f_{j,m(j)} \right).$$

In the appendix, we show that this choice can be uniquely characterized. Firms with higher innovation effort $x_f$ import a weakly larger set of innovation services and thus display higher import intensities according to Proposition 2.

### 4.5 Key Predictions

We collect key predictions that we will take to the data in the following proposition.

**Proposition 3** The model implies the following relationships:

1. **Imports of innovation-related services:** Firms with higher levels of foreign innovation imports have larger overall innovation expenditures and innovate more.

2. **Exports:** Firms with higher levels of exports (both on the extensive and intensive margin) innovate more.

3. **Competition:** Firms with higher profit margins innovate more.

**Proof.** Please see Appendix B.2.

Proposition 3 provides testable implications for the relationship between firms’ innovation activity, foreign innovation service imports, exports, and competition. The first prediction is borne out of the relationship between foreign innovation imports and the cost of innovation. The second prediction stems from a standard market size effect. The last prediction implies that increased levels of competition reduce innovation activity if profit margins respond negatively to competition.\(^{16}\)

\(^{16}\) However, mark-ups and in particular, their elasticity with respect to more innovation activity may be non-monotone in sales market shares. As a consequence, the model predicts no linear relationship...
5 Empirical Evidence

In this section, we test the key predictions of our theoretical model. We investigate the effect of our three variables of interest – innovation service imports, exports, and competition – on firms’ innovation activities.

5.1 Specification

Letting \( f \) index firms, \( s \) index 2 digit NACE Rev. 1 manufacturing industries and \( t \) index the years from 2001 to 2012, we consider regressions of the following form:

\[
y_{f,t} = \alpha \cdot \log(1 + \text{Innovation Imports}_{f,t}) + \beta \cdot \log(1 + \text{Exp}_{f,t}) + \gamma \cdot \text{Comp}_{f,t} + \delta \cdot \text{X}_{f,t} + \omega_{s,t} + \epsilon_{f,t}. \tag{5.1}
\]

\( y_{f,t} \) denotes innovation measures at the firm level. The main predictions of our model are in terms of innovation expenditures. We also include R&D expenditures as an alternative measure of innovation inputs. As our data also allows us to observe innovation outcomes, such as product and process related measures of innovation success, we include these in our analysis as well.

\( \text{Innovation Imports}_{f,t} \) and \( \text{Exp}_{f,t} \) measure the value of firm-level innovation service imports and export revenues. \( \text{Comp}_{f,t} \) is a measure for a firm’s competitive environment that will be described shortly.

\( \omega_{s,t} \) denotes industry-year fixed effects. The inclusion of fixed effects ensures that our estimates do not reflect variation across industries and instead are driven by variation across firms within industries. \( \text{X}_{f,t} \) is a vector of time-varying firm characteristics. It contains three binary variables: one indicating if a firm is part of an FDI relation, one indicating if a firm is located in East Germany, and one indicating if a firm performs internal R&D at least occasionally. Moreover, it includes a firm’s number of employees as a proxy for size as well as the average wage of a firm’s industry within East- or West Germany as a proxy for cost shocks.

The parameters of interest are the coefficients \( \alpha, \beta \) and \( \gamma \) which measure the impact of trade in innovation services, exports and profit margins on firm-level innovation activities respectively. To identify causal effects, we construct firm-level instrumental variables for exports and service imports.

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*between changes in competition and changes in innovation activity. Fieler & Harrison (2018) stress that increases in competition may cause more innovation through an import-competition escape effect. While we don’t model this explicitly, our model does not rule such mechanisms out.*
5.2 Instrumental Variables

5.2.1 Imports of Foreign Innovation Services

Firms might become more innovative by importing more innovation services. However, firms might also import more innovation services because they innovate more. To address this reverse causality, we construct a firm-level supply shock by implementing a standard Bartik instrument approach.

To construct the shift-share instrument, we consider a firm $f$ that is observed importing foreign innovation services for the first time in year $t_0$. Denote by $\omega_{f,n,t_0}^{\text{Imp\,Innov}}$ the share of the expenditures on foreign innovation output that is sourced from origin country $n$. Further, denote by $\text{IMP}^{\text{Innovation}_{n,f,t}}$ the total value of year $t$ imports of foreign innovation by all German firms from country $n$ that are not in the same NACE Rev.1 two digit industry as firm $n$.

The instrument for firm $f$’s imports of foreign innovation services in year $t$ is defined as the sum of the aggregate innovation imports by all firms not in firm $f$’s industry over all countries, weighted by firm $f$’s initial import share from country $n$:

$$Z_{f,t}^{\text{Imp\,Innov}} = \sum_n \omega_{f,n,t_0}^{\text{Imp\,Innov}} \text{IMP}^{\text{Innovation}_{n,f,t}}.$$  \hspace{1cm} (5.2)

Aggregate innovation service imports measure shocks to the supply of innovation services from a specific country. The initial shares imply differences in firm exposure to these supply shocks.\textsuperscript{17}

The aggregation of innovation service imports for firms not in the same industry as firm $f$ ensures that the aggregate supply shock is exogenous. Earlier, we have shown that large firms account for a large share of total innovation services. Aggregate changes in innovation imports of $f$’s own industry could thus reflect changes in the behavior of $f$ itself. By excluding a firm’s own industry when constructing the supply shocks, we aim to minimize this threat to exogeneity.

5.2.2 Exports

We construct an instrument for exports by constructing exogenous firm-level demand shocks. The logic of the instrument is symmetric to the supply shocks constructed in

\hspace{1cm} \textsuperscript{17}The theoretical framework microfound the construction of our instrument. More specifically, our model predicts that the responsiveness of a firm’s innovation activity to shocks in the cost of foreign trade in services will be a function of the firm’s initial import shares. Intuitively speaking: Firms that rely more on foreign innovation services as an input to their own innovation activities will be affected stronger by changes in the cost of importing services as their innovation costs depend more on them.
the previous section.

Consider a firm \( f \) that is first observed in year \( t_0 \) and denote by \( \omega^{\text{EXP}}_{f,t_0} \) the share of its total revenues that is accounted for by exports. Let \( \text{IMP}^\text{World}_{s(f),t} \) denote the value of world imports of industry \( s \) in year \( t \). The instrument for exports for firm \( f \) in year \( t \) is then defined as:

\[
\text{bartik}^{\text{EXP}}_{f,t} = \omega^{\text{EXP}}_{f,t_0} \cdot \text{IMP}^\text{World}_{s(f),t}.
\]  

(5.3)

Changes in the aggregate import demand of a given industry act as demand shocks. We argue that these shocks are exogenous to changes in the innovation activity of individual German firms. Weighting the industry-level shocks with a firm’s initial export shares generates variation in exposure to the export demand shock across firms.\(^\text{18}\)

### 5.2.3 Competition Measure

Following Lim et al. (2018), we measure competition in an industry by the number of active domestic firms in a given two-digit NACE Rev. 1 industry. To generate variation in competition exposure across firms within a given industry, we interact with this measure a firm’s position in its industry’s domestic sales distribution. Firms located in higher deciles of their industry’s sales distribution have higher market shares, which, according to our framework, directly affects their exposure to competition.

Let \( \tilde{d}_{f,s,t} \) denote a variable that takes the value 1 if firm \( f \) is in the top decile of the domestic sales distribution in industry \( s \) in year \( t \), the value 2 if firm \( f \) is in the second-highest decile and henceforth until it takes the value 10 for a firm in the lowest decile. In addition, denote by \( n_{s,t} \) the number of active firms in industry \( s \) in year \( t \). The competition variable combines both measures as follows:

\[
\text{comp}^2_{f,t} = \tilde{d}_{f,s,t_0} \times \log (n_{s,t}).
\]  

(5.4)

Our empirical competition measure of competition takes higher values for smaller firms that are active in industries with more competitors. We treat the number of firms in any given year to be exogenous to the actions and shocks affecting individual firms. As we observe industries at the two-digit level, we think that this assumption is appropriate. Further, to ensure that a firm’s position in its industry’s sales distribution is not correlated with unobserved factors affecting innovation, we hold this variable’s value fixed at the value that it attained in the first year \( t_0 \) in which \( f \) is observed and exclude the firm-year observation from the sample.

\(^{18}\) Again, this construction is consistent with the structural model.
5.3 Results

5.3.1 OLS

A simple OLS regression serves as a first check on the key predictions of our model regarding the cross-sectional equilibrium correlation between innovation efforts and innovation service imports, exports as well as competition. Table 5.1 presents the results of estimating the full specification in (5.1) via OLS across all innovation outcomes of interest.

Innovation Inputs  Our theoretical framework predicts that firms with higher levels of innovation service imports and exports spend more resources on innovative activities. The first two columns of Table 5.1 show that this prediction is confirmed by the conditional correlations obtained through our OLS regression. Firms with higher levels of innovation imports and exports spend larger overall amounts on both innovation activities as a whole and R&D in particular.

We find that competition correlates negatively with overall innovation expenditures. Simultaneously, we find a statistically significant positive relationship between competition and R&D expenditures. As we will see below, only the former effects remain statistically significant in the second-stage IV estimates.

Innovation Outcomes  Higher levels of innovation service imports are positively related to all measures of innovation success. As higher levels of innovation expenditures are positively related to better innovation outcomes, we interpret this as further validation of the cross-sectional predictions of our model.

Exports correlate positively with revenues generated by new products. However, we cannot detect a statistically significant relationship between higher levels of exports and better process innovation outcomes.

Our results indicate that while higher exposure to competition relates to better product innovation outcomes, it is simultaneously correlated with worse process innovation outcomes. As such, these results may shed light on the ambiguous effects that the literature assigns to competition as a determinant firm-level innovation activity. Consistent with the findings in Fieler & Harrison (2018), the results indicate that higher competitive pressure might induce firms to innovate on products in order to escape competition in other product markets. Interpreted through the lens of our model, higher levels of competition reduce the elasticity of mark-ups with respect to market shares and reduce the incentives for firms to invest in cost-saving technologies in order to solidify market shares and thus profit margins.
### Table 5.1  OLS Results

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Expenditures</th>
<th>Outcomes</th>
<th>Sales Products New to</th>
<th>Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Innov. Imports</td>
<td>R&amp;D</td>
<td>Firm</td>
<td>Firm &amp; Market</td>
</tr>
<tr>
<td></td>
<td>Innov. Imports</td>
<td>0.10***</td>
<td>0.12***</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>(4.84)</td>
<td>(6.25)</td>
<td>(1.55)</td>
<td>(2.01)</td>
</tr>
<tr>
<td></td>
<td>Exports</td>
<td>0.06***</td>
<td>0.03***</td>
<td>0.11***</td>
</tr>
<tr>
<td></td>
<td>(7.57)</td>
<td>(7.30)</td>
<td>(8.52)</td>
<td>(8.61)</td>
</tr>
<tr>
<td></td>
<td>Competition</td>
<td>-0.005***</td>
<td>0.004***</td>
<td>-0.003</td>
</tr>
<tr>
<td></td>
<td>(-2.63)</td>
<td>(2.75)</td>
<td>(-0.76)</td>
<td>(1.92)</td>
</tr>
</tbody>
</table>

| Controls | | | | | | | |
|----------|---------------|----------|-----------------------|-----------|
| Labor Cost | -0.05 | -0.06 | -0.22 | -0.09 | -0.25 | 0.57 | 0.53 |
| Employment | 0.53*** | 0.47*** | 0.58*** | 0.48*** | 0.35*** | 0.71*** | 0.26*** |
| East | -0.01 | 0.02 | 0.19 | -0.37 | 0.56** | -0.66*** | -0.01 |
| Multinational | -0.08 | 0.44 | 0.42 | 0.17 | 0.05 | 0.58 | -0.13 |

| Observations | 17890 |
| Firms | 722 |
| $R^2$ | 0.65 |
| Year-Ind FE | ✓ |

Notes: This table presents the OLS results of estimating equation (5.1) on the baseline sample of German manufacturing firms. T-statistics are in parentheses and clustered at the firm level. *** indicates significance at the 1%, ** at the 5% and * at the 10% level.

Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Trade in Service Statistics (SITS), Microdatabase Directinvestment (MiDi); Leibniz Centre for European Economic Research Mannheim Innovation Panel (MIP), 2002-2011, own calculations.

#### 5.3.2 Second Stage

Table A.5 displays the first-stage regressions of the full set of instruments on innovation service import intensities and exports. We find a strong first stage for both, as evident by the $F$-statistics.\(^{19}\)

Table 5.2 presents the second-stage IV estimates.\(^{20}\) We find support for the hypothesis that relatively greater access to foreign innovation services leads to relatively higher innovation activity, as well as overall better innovation outcomes. We find statistically significant effects on near all innovation outcomes. This lends further support to our modeling assumption that foreign innovation services provide firms with greater over-

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\(^{19}\) The correlation structure between the instrumented variables is displayed in Table A.6. Evidently, the fitted values entering the second stage regression are far from collinear.

\(^{20}\) We do apply the standard error adjustment to proposed in Adao et al. (2018). A future version of this paper will provide updated standard errors.
**Table 5.2  Second Stage Results**

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Expenditures</th>
<th>Outcomes</th>
<th>Sales Products New to</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Innovation</td>
<td>R&amp;D</td>
<td>Firm</td>
<td>Firm &amp; Market</td>
</tr>
<tr>
<td>Innov. Imports</td>
<td>0.09***</td>
<td>0.13***</td>
<td>0.09</td>
<td>0.21*</td>
</tr>
<tr>
<td></td>
<td>(3.79)</td>
<td>(5.01)</td>
<td>(0.97)</td>
<td>(1.85)</td>
</tr>
<tr>
<td>Exports</td>
<td>0.07***</td>
<td>0.06***</td>
<td>0.14***</td>
<td>0.14***</td>
</tr>
<tr>
<td></td>
<td>(4.59)</td>
<td>(6.32)</td>
<td>(4.65)</td>
<td>(4.49)</td>
</tr>
<tr>
<td>Competition</td>
<td>-0.006*</td>
<td>0.003</td>
<td>-0.006</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>(-1.89)</td>
<td>(1.31)</td>
<td>(-1.19)</td>
<td>(0.77)</td>
</tr>
<tr>
<td>Observations</td>
<td>10666</td>
<td>10666</td>
<td>10666</td>
<td>10666</td>
</tr>
<tr>
<td>Firms</td>
<td>3974</td>
<td>3974</td>
<td>3974</td>
<td>3974</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.67</td>
<td>0.85</td>
<td>0.45</td>
<td>0.22</td>
</tr>
<tr>
<td>Year-Ind FE</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Notes:** Second stage IV results of estimating equation (5.1) on our baseline sample of German manufacturing firms. t-statistics are displayed in parentheses. Standard errors are clustered at the firm level. *** indicates significance at the 1%, ** at the 5% and * at the 10% level. Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Trade in Service Statistics (SITS), Microdatabase Directinvestment (MiDi); Leibniz Centre for European Economic Research Mannheim Innovation Panel (MIP), 2002-2011, own calculations.

all innovation efficiency, independently of whether innovative efforts target product or process innovation.

As indicated by the second row in Table 5.2, firms with relatively larger exposure to foreign export demand shocks undertake larger innovation efforts. We find that higher exposure to demand shocks incentivizes firms to adopt or develop new products, as indicated by increased product innovation revenues. Conversely, we do not find that market size has a statistically significant effect on process innovation, implying that innovation efforts induced through scale primarily materialize through product innovation.

We find that competition has a statistically significant negative effect on innovation expenditures. The effect on R&D expenditures is positive, as in the OLS regression, however not statistically significant. In line with the OLS estimates, we find that higher levels of competition disincentivize firms to invest in cost-saving innovations. However, we cannot detect a statistically significant effect on product innovation. Our findings are thus consistent with the theoretical model’s predictions: Higher levels of competition may reduce the responsiveness of profit margins to market shares and therefore disincentivize firms to undertake innovations that allow them to undertake competitor’s prices.
5.4 Robustness

We check the robustness of our baseline results across multiple dimensions. First, we augment the construction of our export demand and innovation service supply shocks to address potential shortcomings stemming from the fact that the firm-level variation stems from the shift-shares in the Bartik instrument. Second, we show that our empirical results are robust to variations in the baseline sample; more specifically, they remain largely unaltered when only years before the financial crisis are considered. Due to the limitation of 10,000 words, robustness checks are only available upon request.

6 Conclusion

This paper uncovers new dimensions of the connection between trade integration and innovation. We use an unusually detailed dataset that allows us to conduct the first study into the connection between trade in services, trade in goods, and firm-level innovation activity.

We have provided novel descriptive statistics that suggest that firm-level differences in innovation activity are essential for shaping aggregate trends in innovation, that document that trade in foreign knowledge exhibits similar properties to trade in goods and, lastly, that suggest the existence of complementarities in the selection of firms into innovating, exporting goods and importing foreign knowledge.

We have developed a new theoretical model of trade in services, and innovation rationalizes these facts. We empirically tested its key predictions. Our results imply that the firm-level effects of trade in innovation services on firm innovation are of similar magnitudes to the effects of trade that operate through export opportunities and competition.

Further, we have highlighted that complementarities in selection have the potential to amplify the effects of trade integration on aggregate innovation activity through disproportionally incentivizing the largest and most productive firms to innovate more.
References


Garin, Andrew and Filipe Silvero, ‘How Responsive are Wages to Demand within the Firm? Evidence from Idiosyncratic Export Demand Shocks.’ working paper, 2018.


A Table and Figure Appendix

**Figure A.1 World Trade in R&D services**

Notes: The right figure shows the percentage share of R&D service imports as a fraction of world imports in trade in services from 2000 to 2010. Source: ‘Trade in Services’ database, World Bank. The left figure shows world volumes of trade in R&D services normalized to 2000.
### Table A.1 Sample Descriptive Statistics (unweighted)

<table>
<thead>
<tr>
<th>Description</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment</td>
<td>249.48</td>
</tr>
<tr>
<td>Revenues ($\times 10^3$)</td>
<td>57,037</td>
</tr>
<tr>
<td>Share of Exporters</td>
<td>68.2</td>
</tr>
<tr>
<td>Share Exports in Sales</td>
<td>20</td>
</tr>
<tr>
<td>Share Innovators</td>
<td>69</td>
</tr>
<tr>
<td>Share Innovation Service Importers</td>
<td>3.1</td>
</tr>
<tr>
<td>Share Innovation Service Exporters</td>
<td>1.2</td>
</tr>
<tr>
<td>Share Multinationals</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Notes: (where applicable) averages over all firm-year observations. All shares in percent. Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Trade in Service Statistics (SITS), Microdatabase Directinvestment (MiDi); Leibniz Centre for European Economic Research Mannheim Innovation Panel (MIP), 2002-2011, own calculations.
Table A.2  Innovation Activity in German Manufacturing Firms

<table>
<thead>
<tr>
<th>Innovation Measure</th>
<th>Sample</th>
<th>Multinationals</th>
<th>Innov. Importers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inputs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Innovation Expenditures</td>
<td>4752</td>
<td>13162</td>
<td>26129</td>
</tr>
<tr>
<td>R&amp;D Expenditures</td>
<td>2950</td>
<td>8621</td>
<td>14838</td>
</tr>
<tr>
<td>R&amp;D Imports</td>
<td>227</td>
<td>1827</td>
<td></td>
</tr>
<tr>
<td>Continuous R&amp;D (%)</td>
<td>82</td>
<td>93</td>
<td>93</td>
</tr>
<tr>
<td><strong>Outcomes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product innovator (%)</td>
<td>74</td>
<td>82</td>
<td>83</td>
</tr>
<tr>
<td>Revenue Share Products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>improved/new to firm</td>
<td>20.4</td>
<td>18.89</td>
<td>22.8</td>
</tr>
<tr>
<td>new to market</td>
<td>5.8</td>
<td>4.9</td>
<td>7.6</td>
</tr>
<tr>
<td>new product</td>
<td>5.7</td>
<td>4.2</td>
<td>6.6</td>
</tr>
<tr>
<td>Process innovator (%)</td>
<td>49.9</td>
<td>58</td>
<td>61</td>
</tr>
<tr>
<td>Reduction of unit cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes?</td>
<td>32.9</td>
<td></td>
<td>45.1</td>
</tr>
<tr>
<td>In percent</td>
<td>3.0</td>
<td>3.5</td>
<td>3.6</td>
</tr>
<tr>
<td>Increase in Quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes?</td>
<td>34.2</td>
<td></td>
<td>40.2</td>
</tr>
<tr>
<td>In percent</td>
<td>2.8</td>
<td>2.7</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Notes: Averages across all firm year observations with positive innovation expenditures. Revenues, innovation expenditures and imports of foreign innovation services are in Euro thousands. Source: Rearch Data and Service Centre (RDSC) of the Deutsche Bundesbank, Trade in Service Statistics (SITS), Microdatabase Directinvestment (MiDi); Leibniz Centre for European Economic Research Mannheim Innovation Panel (MIP), 2002-2011, own calculations.
Table A.3  Firm Status and Productivity Measures

<table>
<thead>
<tr>
<th></th>
<th>Innovation Imp.</th>
<th>Exporter</th>
<th>Innovator</th>
<th>Innovation Exp.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rev/L</strong></td>
<td>0.03***</td>
<td>0.15***</td>
<td>0.09***</td>
<td>0.01***</td>
</tr>
<tr>
<td></td>
<td>(7.97)</td>
<td>(19.7)</td>
<td>(11.2)</td>
<td>(3.24)</td>
</tr>
<tr>
<td><strong>Skill Intensity</strong></td>
<td>0.001***</td>
<td>0.002***</td>
<td>0.004***</td>
<td>0.000***</td>
</tr>
<tr>
<td></td>
<td>(3.08)</td>
<td>(6.0)</td>
<td>(12.5)</td>
<td>(3.09)</td>
</tr>
<tr>
<td><strong>East Germany</strong></td>
<td>-0.01***</td>
<td>-0.10***</td>
<td>-0.002</td>
<td>-0.01***</td>
</tr>
<tr>
<td></td>
<td>(-3.51)</td>
<td>(-5.7)</td>
<td>(-0.19)</td>
<td>(-2.06)</td>
</tr>
</tbody>
</table>

Notes: Estimation results of regressing a dummy for a firm’s trade participation and innovation activity on controls and a firm’s labor revenue product, denoted Rev/L. Standard errors are in parentheses and clustered at the firm level. *** indicates significance at the 1%, ** at the 5% and * at the 10% level. Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Trade in Service Statistics (SITS), Microdatabase Directinvestment (MiDi); Leibniz Centre for European Economic Research Mannheim Innovation Panel (MIP), 2002-2011, own calculations.

Table A.4  Conditional Sample Composition

<table>
<thead>
<tr>
<th></th>
<th>Multinat.</th>
<th>Imp. Innov. Serv.</th>
<th>Exporter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multinational</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>100</td>
<td>22.5</td>
<td>69</td>
</tr>
<tr>
<td>No</td>
<td>100</td>
<td>2</td>
<td>48</td>
</tr>
<tr>
<td><strong>Importer Innov. Serv.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>54</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>No</td>
<td>7</td>
<td>100</td>
<td>50</td>
</tr>
</tbody>
</table>

Notes: Conditional sample composition of innovating firms (firms with strictly positive innovation expenditures). Read: Conditional on having status x (row), what share of firms has status y (column). Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Trade in Service Statistics (SITS), Microdatabase Directinvestment (MiDi); Leibniz Centre for European Economic Research Mannheim Innovation Panel (MIP), 2002-2011, own calculations.
### Table A.5  Baseline First-Stage Results

<table>
<thead>
<tr>
<th></th>
<th>Innovation Imports</th>
<th>Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument Innovation Imports</td>
<td>0.53*** (22.11)</td>
<td>0.16*** (6.71)</td>
</tr>
<tr>
<td>Instrument Exports</td>
<td>-0.00 (-0.17)</td>
<td>0.86*** (36.53)</td>
</tr>
<tr>
<td>Observations</td>
<td>10,666</td>
<td>10,666</td>
</tr>
<tr>
<td>Unique Firms</td>
<td>3,974</td>
<td>3,974</td>
</tr>
<tr>
<td>F-Statistic</td>
<td>253.13</td>
<td>728.48</td>
</tr>
<tr>
<td>Year×Industry FE</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Notes: First Stage results of projecting endogenous outcomes on the instruments constructed in Section 5.2. Standard errors are in parentheses and clustered at the firm level. "***" indicates significance at the 1%, "**" at the 5% and "*" at the 10% level. Source: Reasearch Data and Service Centre (RDSC) of the Deutsche Bundesbank, Trade in Service Statistics (SITS), Microdatabase Directinvestment (MiDi); Leibniz Centre for European Economic Research Mannheim Innovation Panel (MIP), 2002-2011, own calculations.

### Table A.6  Baseline: Correlations between instrumented independent variables

<table>
<thead>
<tr>
<th></th>
<th>Innovation Imports</th>
<th>Exports</th>
<th>Competition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation Imports</td>
<td>1</td>
<td>1</td>
<td>-0.25</td>
</tr>
<tr>
<td>Exports</td>
<td>0.21</td>
<td>0.25</td>
<td>1</td>
</tr>
<tr>
<td>Competition</td>
<td>-0.14</td>
<td>-0.25</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: This table presents the correlation between the fitted first stage variables for innovation imports and exports, as well as competition. Source: Reasearch Data and Service Centre (RDSC) of the Deutsche Bundesbank, Trade in Service Statistics (SITS), Microdatabase Directinvestment (MiDi); Leibniz Centre for European Economic Research Mannheim Innovation Panel (MIP), 2002-2011, own calculations.
Table A.7 Second-Stage IV Results for Alternative Instruments for Exports and Innovation Imports

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Expenditures</th>
<th>Sales Products New to Process</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Innovation</td>
<td>Firm</td>
<td>Unit Cost</td>
</tr>
<tr>
<td>Exports</td>
<td>Innovation</td>
<td>Imports</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R&amp;D</td>
<td>0.08*</td>
<td>0.10***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.71)</td>
<td>(2.54)</td>
</tr>
<tr>
<td>Competition</td>
<td>0.07***</td>
<td>0.06***</td>
<td>0.17***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.2)</td>
<td>(4.60)</td>
</tr>
<tr>
<td></td>
<td>-0.006</td>
<td>0.006**</td>
<td>-0.005</td>
</tr>
<tr>
<td></td>
<td>(-1.55)</td>
<td>(2.26)</td>
<td>(-0.75)</td>
</tr>
<tr>
<td>Observations</td>
<td>6361</td>
<td>6361</td>
<td>6361</td>
</tr>
<tr>
<td>Unique Firms</td>
<td>2659</td>
<td>2659</td>
<td>2659</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.68</td>
<td>0.86</td>
<td>0.45</td>
</tr>
<tr>
<td>First-stage $F$</td>
<td>599.0</td>
<td>214.1</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Second stage results of estimating equation (5.1) on our baseline sample of German manufacturing firms. Standard errors are in parentheses and clustered at the firm level. "***" indicates significance at the 1%, "**" at the 5% and "*" at the 10% level. Firm controls include local labor cost, total employment, and indicator variables for whether a firm conducts R&D continuously, is located in former Eastern German States and is a multinational. Source: Reasearch Data and Service Centre (RDSC) of the Deutsche Bundesbank, Trade in Service Statistics (SITS), Microdatabase Directinvestment (MiDi); Leibniz Centre for European Economic Research Mannheim Innovation Panel (MIP), 2002-2011, own calculations.
Table A.8  **Second Stage IV Results for pre 2008 sample**

<table>
<thead>
<tr>
<th></th>
<th>Inputs Expenditures</th>
<th></th>
<th>Outcomes Sales Products New to Firm</th>
<th></th>
<th></th>
<th>Process</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Innovation</td>
<td>R&amp;D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Innovation Imports</td>
<td>0.08**</td>
<td>0.11***</td>
<td>0.021</td>
<td>0.24*</td>
<td>0.21</td>
<td>0.26**</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>(2.12)</td>
<td>(3.26)</td>
<td>(0.15)</td>
<td>(1.80)</td>
<td>(1.53)</td>
<td>(1.99)</td>
<td>(1.17)</td>
</tr>
<tr>
<td>Exports</td>
<td>0.07***</td>
<td>0.07***</td>
<td>0.17***</td>
<td>0.20***</td>
<td>0.12***</td>
<td>0.02</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>(3.49)</td>
<td>(4.82)</td>
<td>(4.63)</td>
<td>(4.02)</td>
<td>(2.43)</td>
<td>(0.05)</td>
<td>(-0.41)</td>
</tr>
<tr>
<td>Competition</td>
<td>-0.009**</td>
<td>-0.002</td>
<td>-0.005</td>
<td>0.001</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.008</td>
</tr>
<tr>
<td></td>
<td>(-2.15)</td>
<td>(-0.55)</td>
<td>(-0.75)</td>
<td>(0.07)</td>
<td>(-1.28)</td>
<td>(-1.16)</td>
<td>(-0.97)</td>
</tr>
<tr>
<td>Observations</td>
<td>4109</td>
<td>4109</td>
<td>4109</td>
<td>4109</td>
<td>4109</td>
<td>4109</td>
<td>4109</td>
</tr>
<tr>
<td>Unique Firms</td>
<td>2076</td>
<td>2076</td>
<td>2076</td>
<td>2076</td>
<td>2076</td>
<td>2076</td>
<td>2076</td>
</tr>
<tr>
<td>First-stage $F$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exports</td>
<td>495.21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Innovation Imports</td>
<td>144.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm Controls</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Year×Sector FE</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Notes: Second stage results of estimating equation (5.1) on our baseline sample of German manufacturing firms. Standard errors are in parentheses and clustered at the firm level. ** indicates significance at the 1%, * at the 5% and * at the 10% level. Firm controls include local labor cost, total employment, and indicator variables for whether a firm conducts R&D continuously, is located in former Eastern German States and is a multinational. Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Trade in Service Statistics (SITS), Microdatabase Directinvestment (MiDi); Leibniz Centre for European Economic Research Mannheim Innovation Panel (MIP), 2002-2011, own calculations.
B  Technical Appendix

B.1  Proposition 2

Proof. Due to the limitation of 10,000 words, the technical appendix is momentarily only available upon request.

B.2  Proposition 3

Proof. Due to the limitation of 10,000 words, the technical appendix is momentarily only available upon request.

B.3  Proposition 4 and 5

Proof. Due to the limitation of 10,000 words, the technical appendix is momentarily only available upon request.