Department for Business & Trade

The relationship between trade and productivity: a feasibility study

LSE Consulting

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Abbreviations

AVE	Ad valorem equivalent
BoP	Balance of Payments
DBT	Department for Business and Trade
EFTA	European Free Trade Area
FTA	Free Trade Agreement
FDI	Foreign Direct Investment
GATT	General Agreement on Tariffs and Trade
GATS	General Agreement on Trade in Services
GFS	Government Finance Statistics
GTAP	Global Trade Analysis Project
GSS	Government Statistical Service
HS	Harmonised System
ICT	Information and Communications Technology
IDBR	Inter-Departmental Business Register
IMF	International Monetary Fund
IPR	Intellectual Property Rights
ITIS	ONS' International Trade in Services
ISIC	International Standard Industrial Classification
MFN	Most Favoured Nation
NTM	Non-tariff measures
OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics
PPML	Poisson Pseudo Maximum Likelihood
STRI	Services Trade Restrictiveness Index
TiVA	Trade in value-added
TRAINS	Trade Analysis Information System
TRIPS	Trade-Related Aspects of Intellectual Property Rights

UNCTAD	United Nations Conference on Trade and Development
WCO	World Customs Organisation
WIOD	World Input-Output Tables
WTO	World Trade Organisation

Glossary

Complementarity	The phenomenon where the appeal of a product increases with the popularity of another complement product
Cost complementarity	The phenomenon where the marginal cost of producing one type of output decreases when the output of another good increases
Endogeneity	Bias when the predictor variable in a regression model is correlated with the error term. Often caused by self-selection (see below)
GVA per worker	Gross value added per worker (metric of labour productivity deployed by ONS)
Input tariff reduction	Reduction of duties on inputs
Intermediate input	Goods and services used in the production process of other goods
Labour productivity	Output produced for each unit of labour input
Self-selection	Bias caused by individuals selecting themselves into a certain group, e.g., productive firms are more likely to trade to begin with
Total factor productivity (TFP)	Output produced by a range of inputs (typically labour and capital)

Contents

List of Figures

List of Tables

Executive Summary

Background and Study Objectives

The aim of this feasibility study is to understand the evidence base on the role trade can play in facilitating growth and productivity at the UK national, sectoral, and firm level. To achieve this objective, this study has investigated the following four research questions:

1) What are the recent literature and empirical findings on the mechanisms that explain the relationship between the exporting / importing status of firms and their productivity, including how productivity is defined?
2) How do strictly importing firms perform on productivity levels against strictly exporting firms? What, if any, are the impacts of trade frictions on productivity?
3) How can we quantify the impact of changes in trade on productivity and consequently impacts to the economy, businesses, and jobs of UK nations *(i.e., Scotland, Wales, and Northern Ireland*)/English regions?
4) What are the different approaches to measuring the impact of trade on productivity at the UK, sector, and firm level?

To answer these questions, the relevant academic literature has been reviewed. Where possible, the review has used only recent publications (from 2007 onwards) for countries that are relatively similar to the UK in economic terms. However, on some occasions, there was no literature available with direct applicability to the UK context and thus studies for other countries have been reviewed as well. In addition, it has not always been possible to find data at the sectoral or firm level. The review below will clearly highlight when this was the case and make recommendations to address evidence gaps.

To ensure the reviewed studies are of sufficient quality to allow robust conclusions, the review has focused on peer-reviewed studies published in high-quality academic journals and has also carried out an independent assessment of the reliability of the literature included. Where conclusions were judged to be potentially unreliable due to methodological issues, this has been clearly highlighted during the discussion of the relevant results.

Findings and Implications

The review of the pertinent academic literature has led to the following conclusions regarding the four research questions mentioned above:

1) What are the recent literature and empirical findings on the mechanisms that explain the relationship between the exporting/importing status of firms and their productivity, including how productivity is defined?

There is consistent evidence in the literature that exporters are about 20-40% more productive than non-exporting firms.[1] As a best central estimate, between 2008 and 2016, UK businesses which report goods exports were 21% more productive than businesses which do not trade after controlling for their size, industry, and ownership status (ESCoE, 2018).[2] This productivity advantage results from two mechanisms.

- First, more productive firms are more likely to export because they can afford to cover the entry costs for accessing export markets[3].
- Second, there is also evidence that productivity is increased by exporting, due to two mechanisms.
    - First, there is a "learning-by-exporting" process, where UK firms can learn from international clients and competitors and catch up with more productive international peers, especially when exporting to advanced economies[4].
    - Secondly, exporting has an impact on innovation, because exporting supports productivity-enhancing innovations by increasing the scale of operations[5].

The overall effect of exporting on productivity varies with firm-level characteristics, with the impact of learning being most significant for the initially least productive firms and the impact of exporting on innovation being larger for those firms that are initially most productive and able to export to advanced economies.

The fact that more productive firms are more likely to export suggests that a key lever for government policy to increase exports is to pursue policies that increase the productivity of UK firms, in particular SMEs, to enable them to go onto the next step of their business expansion by starting to trade overseas. Such policy should be implemented in parallel to existing proportional export support and promotion to ensure sustained export success and hence productivity improvements for UK firms, especially SMEs.

Given the range of factors that contribute to productivity, this calls for a combined effort across government to ensure complementary policies that support trade are leveraged. Considering that such productivity improvements will require investment from UK firms, and that investment requires certainty, a key supporting role DBT can play in this context is to ensure long-run stability in the

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[1] Productivity is usually measured as labour productivity in the studies that have been reviewed, although some papers also use measures of total factor productivity. See Section 3.4 for additional details on how these measures are computed.

[2] The central estimate of 21% is derived from "ESCoE, UK trade in goods and productivity: New findings. (2018). This figure is cited as it is drawn from relatively recent research conducted in the context of UK firms. Other figures used to compile the range pertain to other geographies and/or older time periods.

[3] Eaton, J., Kortum, S., & Kramarz, F. (2011). An anatomy of international trade: Evidence from French firms. Econometrica, 79(5), 1453-1498.

[4] Crespi, Criscuolo, and Haskel, J. (2008) "Productivity, exporting, and the learning-by-exporting hypothesis: direct evidence from UK firms" Canadian Journal of Economics vol.41(2) pp.619-638

[5] Aw, B. Y., Roberts, M. J., & Xu, D. Y. (2011). R&D investment, exporting, and productivity dynamics. American Economic Review, 101(4), 1312-1344.

trading environment faced by UK firms, for example by locking in long-term access to key markets through FTAs and by championing free trade and the rules-based multilateral system.

Regarding importing, this review has found an important link between importing and productivity. This is because importing enables businesses to access inputs that are not available domestically (possibly at a lower price), to experiment with new combinations of inputs to optimise production processes and to create new products.

The finding that both exporting and importing are beneficial for productivity suggest that policy makers should continue to use FTAs to lower tariffs and remove other barriers to entry in markets. Lower tariffs on UK imports will stimulate the importing activities of UK firms, while lower tariffs in foreign markets will stimulate entry into these markets and hence UK exports. In this sense, FTAs can be leveraged to harness the productivity-enhancing effects of both importing and exporting.

2) How do strictly importing firms perform on productivity levels against strictly exporting firms? What, if any, are the impacts of trade frictions on productivity?

Firms that manage to engage in both importing and exporting (two-way trade) tend to have a larger productivity advantage, consistent with higher entry costs to two-way trade. The review of the evidence between importing, exporting and productivity has found that there are some commonalities in terms of entry costs between importing and exporting[6]. Studies show that firms engaged in importing are more likely to enter export markets due to the common investments they have already made in acquiring the necessary resources and capabilities for international trade. There is also evidence that jointly exporting and importing confers additional productivity gains to firms, after entry, compared to engaging in one of the two activities only.

The review has also found that importing can have both direct and indirect effects on exporting. Regarding indirect effects, import-induced productivity gains can allow firms to bear the entry costs of exporting and increase the chances of surviving in the competitive export market. Regarding direct effects, importing can boost exporting by helping to improve the quality of exported products through input-product complementarities, and by facilitating knowledge and technology transfer. Furthermore, importing can induce cost savings that can boost the return from exporting.

Barriers to exporting to key foreign markets can increase the costs and complexity of exporting for UK firms and weaken the complementarity between importing and exporting. That is, firms can no longer use their experience from the importing process to help them with exporting, as exporting now faces very

[6] *Kasahara, H., & Lapham, B. (2013). Productivity and the decision to import and export: Theory and evidence. Journal of International Economics, 89(2), 297-316. https://doi.org/10.1016/j.jinteco.2012.08.005*

different challenges from importing. Ultimately, this could imply the exit from the export market for some UK firms.

These links between importing and exporting further strengthen the case for policies that try to improve both the import and export performance of UK firms. One important policy lever is the continued lowering of tariffs through FTAs, to stimulate both importing and exporting activities and thus increase UK productivity.

Finally, the review of the literature on trade frictions has highlighted the negative impact that supply chain disruptions have on the impacted firms' production activities, and subsequently on their domestic sales and exports, which tend to significantly decline. These declines in turn tend to lower firm-level productivity. Accordingly, the review recommends that UK policymakers should refrain from imposing unnecessary restrictions on supply chains through the use of tariffs on intermediate inputs and should instead aim to lower such tariffs, which is likely to significantly increase UK firm-level productivity, subject to the caveat that existing evidence may not be fully relevant to the UK (see Section 3.2.5).

Furthermore, there is also a role for putting robust systems in place that allow firms to handle unexpected financial or supply chain shocks caused by natural disasters such as the Covid pandemic. In this context, this review has highlighted the importance of firms holding enough inventories to allow the weathering of such unexpected shocks.

3) How can we quantify the impact of changes in trade on productivity and consequently impacts on the economy, businesses, and jobs of UK nations *(i.e., Scotland, Wales, and Northern Ireland*)/English regions?

At the UK-, national- and sectoral-level, there is a lack of evidence on what role trade can play in facilitating productivity gains. At the firm-level, data issues have rendered simple statements like "if trade goes up or down by x% then UK productivity increases/decreases by y%" difficult to infer. Nevertheless, the existing literature has revealed that productive UK firms are more likely to engage in international trade, to begin with. This implies that productive UK firms may be more receptive to trade promotion activities undertaken by DBT and other organisations.

There is also good evidence that increases in trade improve UK productivity. This occurs through market share reallocation (more productive firms growing at the expense of less productive ones), but also through within-company productivity growth that results from learning-by-exporting, innovation, and access to imported intermediate inputs, with non-trading firms also benefiting via spillovers from exporting firms.

Research suggests that engaging in international trade is associated with a subsequent increase in firm-level productivity that ranges from 3%-22%[7][8]. As a

[7] *ESCoE. (2018). UK trade in goods and productivity: New findings.*
[8] *ONS. (2018, July 5). UK trade in goods and productivity: New findings.*

best central estimate derived from the most recent causal analysis, engaging in importing and exporting is associated with a subsequent increase in TFP of 6.7% amongst UK firms[9]. These figures are derived from UK-based studies that attempt to isolate the causal effects of engaging with international trade; they should not be compared with the 20-40% range referred to above which measures the correlative relationship between trade and productivity.

Trade-related productivity growth is likely to have a net positive effect on employment and mean employee compensation[10]. No research has attempted to isolate trade-related productivity changes from other trade effects.[11] But improved efficiency has likely fostered an aggregate rise in labour demand through a range of induced effects. These include an increase in employee mean compensation that is broadly equal to any productivity growth. This implies that trade promotion activities and subsequent productivity gains are likely to exhibit a net-positive effect on UK employment and wages.

Drawing conclusions on UK regions and nations has not been possible due to the absence of research on trade and productivity that makes sub-national distinctions. This represents a potential area of future study. For instance, samples could distinguish between NUTS 1 regions to assess regional variation in the extent to which trade affects productivity.

4) What are the different approaches to measuring the impact of trade on productivity at the UK, sector, and firm level?

This review has identified several standard approaches to measuring the impact of trade on UK productivity. More specifically, it provides an overview of the data requirements, and the advantages and disadvantages of methods used to estimate the three main measures of firm-level productivity: labour productivity, total factor productivity, and indirect measures of productivity such as innovation and management quality.

The headline recommendation from the review of the relevant literature is that UK-specific research on the impact of trade on productivity should use matched firm-trade data.[12] More specifically, this review recommends estimating productivity using different measures and methods[13], including the most rigorous control function methods, to ensure the effects are not driven by the choice of the productivity measure. Empirical analyses should also consider different

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[9] *The central estimate of 6.7% is derived from Harris and Moffat (2015). This figure is cited as it is drawn from relatively recent research (2011/12) that deploys robust econometrics to control for endogeneity in assessing the effects of importing and exporting on TFP amongst UK firms. Other figures used to compile the range pertain to importing or exporting and/or older time periods.*

[10] *The Fraser of Allander Institute. (2021). Estimating the relationship between exports and the labour market in the UK.*

[11] *To fill this research gap, a mediation analysis could be deployed similar to the one used by Dhingra et al. (2016) to assess the effects of Brexit (and reduced trade) on living standards. The elasticity of productivity with respect to trade could be combined with the elasticity of employment / wages with respect to productivity to produce an estimate for the effects of trade-related productivity changes on employment / wages.*

[12] *There are two firm-trade matched datasets available. The first dataset has information on matched firm and customs data for the period 2005-2016 (ABS-HMRC). The second has matched administrative and customs data also for the period 2005 to 2016 (IDBR-HMRC). See Section 3.4.4 for details.*

[13] *The most commonly used productivity measures are labour productivity, total factor productivity and indirect indicators of productivity such as innovation measures (e.g., counts of patents). The best methods currently available are the approaches by Olley and Pakes (1996), Levinsohn and Petrin (2003) and Ackerberg et al. (2015). Please see Section 3.4 for details on these methods.*

dimensions of trade, such as importing and exporting, but also differences in export and import scope (e.g., variations in number and type of products/inputs and destinations/origins), and differences between industries and sector characteristics (e.g., in terms of market concentration or technology level).

The report also recommends improving data collection and matching across sources to improve firm and variable coverage. While the available matched firm-trade data offer the opportunity to conduct useful research on the link between trade and productivity, they still have some limitations in terms of sample coverage.[14]

The aim should be to compile a comprehensive dataset that tracks a large and representative sample of firms (in terms of size, sector, and location) over time. Matching firms to trade data also offers the opportunity to incorporate additional variables of interest from other ONS sources, such as R&D investment and other direct measures of innovation (e.g., product and process innovation), and would enable the linking of trade in goods with trade in services data at the firm level.

[14] *At the moment the ABS dataset, which contains all the variables necessary to compute total factor productivity, covers a small sample of firms and the set of small and medium-sized firms covered changes from one year to the next. Consequently, time series data required to study changes in firm-level productivity are only available in the ABS for relatively large firms.*

1 Aims and Objectives

The aim of this feasibility study is to understand the evidence base to inform decisions to support and bolster the United Kingdom's (UK) new high-priority Growth agenda. The research aims to enable the Department for Business and Trade (DBT) to support UK businesses, including small businesses, to harness higher productivity in their trade.

In doing so, it will provide an understanding of the role that trade plays in facilitating growth and productivity at the national, sectoral, and firm level. The results of this study are to be used in support of UK businesses to take full advantage of trade opportunities, including those arising from delivering free trade agreements (FTAs), facilitating UK exports. The study will help achieve the priority outcomes of promoting sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.

Key research questions:

1) What are the recent literature and empirical findings on the mechanisms that explain the relationship between the exporting / importing status of firms and their productivity, including how productivity is defined?
2) How do strictly importing firms perform on productivity levels against strictly exporting firms? What, if any, are the impacts of trade frictions on productivity?
3) How can one quantify the impact of changes in trade on productivity and consequently impacts on the economy, businesses and jobs of the UK nations and English regions?
4) What are the different approaches to measuring the impact of trade on productivity at the UK, sector, and firm level?

2 Methodology

This feasibility study has identified relevant studies through searches in Google Scholar and by using the reference sections of identified papers to identify further related papers (see technical annex for more detail). The insights from this literature review have been used to summarise existing knowledge regarding the four research questions stated above. In doing so, the following search and selection criteria have been applied to each question:

What are the recent literature and empirical findings on the mechanisms that explain the relationship between the exporting / importing status of firms and their productivity, including how productivity is defined?

This section of the literature review has two parts. The first part refers to the relationship between exporting and productivity, considering both how productivity influences participation in the export market, and how exporting

impacts productivity. The second part refers to the relationship between importing and productivity.

In both parts, the review has identified and described the underlying mechanisms that explain the relationship between exporting/importing and productivity. Regarding the scope of the literature review, the objective of the search has been to find at least one high-quality empirical paper for each of the possible mechanisms relating exporting/importing to productivity, and to cover different approaches to measure productivity.[15] The search has focused on peer-reviewed studies published in internationally recognised journals, and only on a few occasions recent not-yet published studies have been used if they were still relevant in terms of descriptive findings (for example ESCoE (2018)).[16] In terms of exporting and productivity, the focus was on studies that explain how productivity influences participation in the export market (and on studies that look at the impact of exporting on productivity.

Regarding the latter, the review has considered studies that look at both the learning-by-exporting mechanism (and studies that look at the impact of exporting on innovation (Aw et al. (2011), Koch et al. (2021), Aghion et al. (2022)). In the case of importing, the focus has been mostly on the impact of importing on productivity, rather than on how productivity influences importing decisions. The review has covered different measures of productivity such as labour productivity total factor productivity (and indirect measures such as innovation

To ensure that the review is based on the most current and relevant findings, it has focused mostly on papers published from 2007 onwards that refer to the UK and countries that are relatively similar to the UK in economic terms (France, Germany, Belgium, Spain, the United States and Canada). On a few occasions the review refers to relatively less advanced economies (e.g., Slovenia, Estonia, Latvia, Hungary) and provides comments on the applicability of the results. While there is also a large literature on trade and productivity in China, these papers have not been considered given the peculiarity of the liberalisation process and rapid economic transition experienced by the Chinese economy over the last decades.

How do strictly importing firms perform on productivity levels against strictly exporting firms What, if any, are the impacts of trade frictions on productivity?

This part of the review consists of two parts, one regarding a productivity comparison between strictly exporting and strictly importing firms, and a second part regarding the impact of trade frictions on productivity.

Regarding the first part, the focus has been on the interactions between importing and exporting as well as, where possible, their relationship with firm-

[15] *See the technical appendix (Section 5), Tables 2-5 for a list of the studies reviewed for this part.*
[16] *Note that the focus on peer-reviewed studies implies that some unpublished papers such as Jibril and Ropa (2022) have been excluded from this review, as they do not pass the necessary quality threshold assured by peer review.*

level productivity.[17] The search has focused on peer-reviewed studies published in internationally recognised journals. The review has compared firms that do not engage in international trade with firms that engage in one-way trade (either importing or exporting) and firms that engage in two-way trade (exporting and importing). As for the previous section, to ensure that the literature review is based on the most current and relevant findings, the focus has been on papers published from 2007 onwards that refer to the UK and countries that are relatively similar to the UK in economic terms (Belgium, France, Ireland, Italy).

Regarding the second part on trade frictions, the review has looked at the link between importing, exporting and productivity and the consequences of disruptions to importing in this context. That is, the object of interest were firms that import intermediate inputs intending to use such imports to produce exports. The review has aimed to understand the consequences of disruptions to imports for the subsequent exports and to learn about the resulting productivity effects.

The first set of papers that has been reviewed to this end analyses the consequences of disruptions to supply chains, focusing on supply chain disruptions caused by natural disasters such as earthquakes and the Covid 19 pandemic, but also looking at disruptions due to policy interventions such as the tariffs imposed by the U.S. under the Trump administration in 2018-2019. The included papers have been selected to provide an overview of the impact of supply chain disruptions on different aspects of firm performance, such as sales, exports, and stock market performance.[18]

The second set of papers that has been included looks at the effects of reducing tariffs on the imports of intermediate inputs. While this literature does not directly examine supply chain disruptions, it also speaks to the consequences of imposing or removing barriers to imports. Two studies of important liberalisation episodes in Indonesia and India have been considered here.[19] Unfortunately, no comparable studies have been carried out for developed economies to date. As a result, this review has needed to make inferences for the UK based on the studies for India and Indonesia. Because of the potentially limited applicability of these results, suggestions for additional empirical work have been made that would yield results more applicable to the UK.

Regarding the scope of the literature review for this second part, the search criteria have been kept open as the amount of literature available on this topic is limited. That is, no restrictions regarding the period or sets of countries covered have been imposed, so as not to overly restrict the scope of the review. However, the review discusses to what extent the available literature can be applied to a UK context.

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[17] See the technical appendix (Section 5), Table 2 for more details on the included studies. Note that while this report will analyse productivity differences between firms with various levels of international activity (e.g., only exporting vs. exporting and importing), there is currently insufficient evidence to directly compare strictly importing firms (i.e., firms that only import) with strictly exporting firms (i.e., firms that only export).

[18] See the technical appendix (Section 5), Tables 6-9 for more details on the reviewed studies.

[19] See the technical appendix (Section 5), Table 9 for details on these studies.

How can one quantify the impact of changes in trade on productivity and consequently impacts on the economy, businesses and jobs of the UK nations and English regions?

This section covers the impact of changes in trade on productivity in the UK context. It also covers the consequent impact of trade-related productivity changes on the UK economy, particularly in terms of both employment and wages.

To quantify the impact of changes in trade on productivity, papers that control for self-selection and attempt to isolate the subsequent productivity gains enjoyed by UK firms engaging in international trade are preferred. However, more recent analyses that assess associations rather than causation are also included for their coverage.[20]

Regarding the scope of the literature review on trade and productivity in the UK context, papers published after 2007 have been favoured for their temporal relevance. In the absence of firm-level data on trade flows, the cited research is confined to assessing changes in firm trading status on productivity.

Identifying research on the consequent impact of trade-related productivity changes on the UK economy proved to be difficult. The principal reason for this seems to be that isolating trade-related productivity changes from other trade effects (heightened demand, import competition etc.) is extremely difficult and, as far as this review found, has not been attempted. To answer this research question, the review has hence referred to the literature documenting the overall effect of trade on UK employment and wages, as well as to the literature on the link between productivity growth and UK employment and wages.

For the literature documenting the overall effect of trade on UK employment and wages, as well as the literature on the link between productivity growth and UK employment and wages, recent research that provides a balanced overview has been favoured. Exceptionally, research on the link between productivity growth and UK employment is less common. A longitudinal study that spans from 1990 to 2017 has been cited here.

What are the different approaches to measuring the impact of trade on productivity at the UK, sector, and firm level?

This final part of the literature review has looked at three main strands of literature. The first strand refers to the approaches used to estimate firm-level productivity, covering labour and total factor productivity. The second refers to the methods used to estimate the impact of trade on productivity. The third and final strand focuses on the UK and refers to the methods that can be used to estimate the impact of trade on productivity using the available data on UK firms. This section also considers the literature that looks at differences in productivity gains across sectors, which however has been found to be limited. Hence, this

[20] *See the technical appendix (Section 5), Table 10 for details on these studies.*

section provides suggestions about possible sector-level disaggregation to be considered in future research.

In terms of the scope of the literature reviewed, the report has covered both methodological papers that explain the estimation of productivity (rationale, assumptions and data requirements) and papers that make specific reference to the measurement of productivity in the context of trade impacts.[21] This section also refers to studies identified in previous sections, which are used as illustrative examples to guide the application of each of the methods. Studies have been selected to provide a comprehensive overview of different methods to help researchers select the most appropriate approach for the desired analysis and available data, while also providing a deeper understanding of the advantages and limitations of each method. For example, some studies cover rigorous methods that can establish causal relationships between trade and productivity, while others rely on less complex methods that can provide a broad overview of the relationship without necessarily establishing causality. In addition, some studies suggest methods that have extensive data requirements, such as detailed firm-level data or longitudinal data, while others rely on more readily available data sources.

The review has covered both direct measures of productivity, such as labour productivity and total factor productivity and indirect measures, such as innovation and management quality. Besides relying on country-specific papers, the review has also considered some review papers that survey the literature on trade and productivity.

[21] *See the technical appendix (Section 5), Table 11 for details on these studies.*

3 Findings and Implications

This section provides detailed responses to the four research questions set out above.

3.1 Relationship between the exporting/importing status of firms and their productivity

3.1.1 Headline Description

The first part of this section reviews the relationship between exporting and productivity, considering both how productivity influences participation in the export market, and how exporting impacts productivity.[22] The second part considers the relationship between importing and productivity. In both parts, the feasibility study identifies and describes the underlying mechanisms.

There is consistent evidence in the literature that exporters are about 20-40% more productive than other firms. As a best central estimate between 2008 and 2016, UK businesses which report goods exports were 21% more productive than businesses which do not trade after controlling for their size, industry, and ownership status (ESCoE, 2018)[23]. **This productivity advantage results from two mechanisms.** First, more productive firms are more likely to export because they can afford to cover the entry costs for accessing export markets. However, there is also evidence that productivity is increased by exporting, due to two mechanisms. First, there is a "learning-by-exporting" process, where firms can learn from international clients and competitors and catch up with more productive international peers, especially when exporting to advanced economies. Secondly, exporting has an impact on innovation because it allows firms to expand their scale of operation, which increases the returns to investment and, in turn, encourages firms to sustain research and development costs to develop new productivity-enhancing products and processes.

The overall effect of exporting varies with firm-level characteristics. For example, the impact of learning to catch up is most significant for the initially least productive firms, while the impact of exporting on innovation is larger for those firms that are initially most productive and able to export to advanced economies.

Regarding importing, access to imported intermediates is another important channel through which trade can boost productivity. Importing intermediate goods can reduce production costs, and allow firms to access higher-quality inputs, find and exploit new complementarities in inputs, and

[22] *Productivity is usually measured as labour productivity in the studies that have been reviewed, although some papers also use measures of total factor productivity. See Section 3.4 for additional details on how these measures are computed.*

[23] *The central estimate of 21% is derived from ESCOE (2018). This figure is cited as it is drawn from relatively recent research conducted in the context of UK firms. Other figures used to compile the range pertain to other geographies and/or older time periods.*

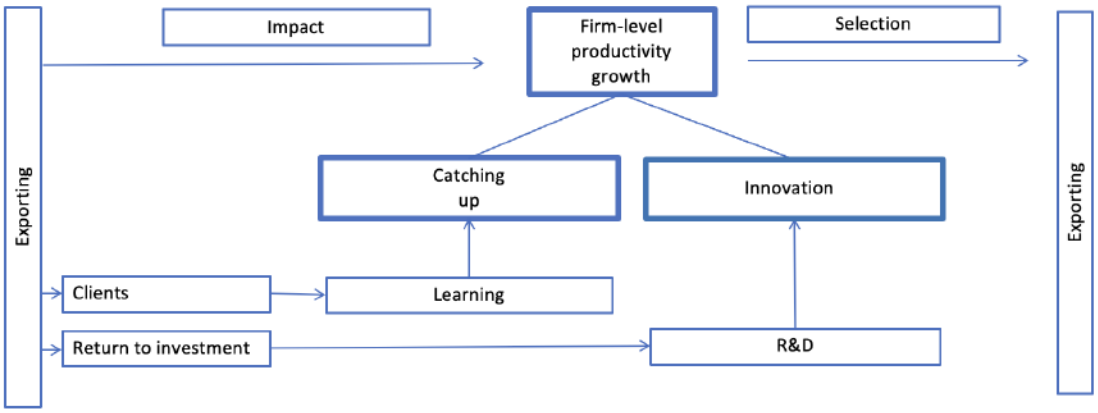
experiment with new combinations of inputs to optimise production processes and create new products.

The positive link between exporting, importing and productivity suggests that trade promotion policy **should include both exporting and importing policy mechanisms to help UK firms, as both forms of trade are associated with higher firm-level productivity.**

3.1.2 Exporting and productivity

The literature on exporting and productivity tends to find that exporters are more productive than domestic-oriented firms. This productivity premium combines two effects. On one hand, more productive firms are more likely to enter the export market (**Selection** channel in ***Figure 1***). On the other hand, exporting can boost firm productivity (**Impact** channel in ***Figure 1***).

Figure 1: Exporting and productivity



Selection into exporting

Exporters are more productive and better-managed firms than non-exporters. While most empirical papers tend to focus on identifying the effects of exporting on productivity, some papers have focused on the selection mechanism and have established that exporters are better organised and more productive firms. This is partly explained by the presence of entry costs. Bloom et al. (2021), for example, using US data, found that better managed firms are more likely to export, and that management is disproportionately more important for trade than for domestic operations. Hansen (2010) analysed the labour productivity of German and Austrian firms and found that exporters are about 40% more productive than non-exporters. Results are very similar for the UK, as Greenaway et al. (2007) found that UK firms entering the export market are 44% more productive (based on total factor productivity estimates) than non-exporters.[24] ESCoE (2018) using more recent data on labour productivity for the UK found that the premium for exporters is around 20%.[25] The productivity premium is found to be lower for trade with the EU (around 4%), consistent with

[24] *See Section 4.3 for a discussion of other UK-specific papers on the productivity advantages of exporters.*
[25] *Note the analysis covers the period 2008-2016 when the UK was in the EU.*

lower barriers to EU goods trade enabling relatively less productive businesses to access these markets.

Among exporters, productivity matters in the choice of export destinations, as exporters able to reach more countries display higher levels of productivity. Eaton et al. (2011) highlight that the decision to export to new markets is not a one-time decision, but that firms continuously re-evaluate new destinations based on changes in their characteristics and market conditions. This suggests that selection into exporting to new markets is an ongoing process, and firms are not necessarily locked into their initial choices. Their model, applied to French data, shows that firm labour productivity increases in the number of countries firms export to, indicating that more productive firms are more likely to have the resources and capabilities to expand into multiple and more diverse international markets. While this paper does not provide specific point estimates, Muuls and Pisu (2009) consider the case of Belgian firms and find that one additional destination is associated with 21% higher labour productivity.

While exporters are on average between 20-40% more productive, they coexist with a considerable number of less-productive exporters that tend to focus on few high-quality products exported to relatively few destinations. This is also known as the “unproductive exporters” paradox and has been observed in several countries, such as Canada (Lileeva and Trefler, 2010) and Germany (Powell and Wagner, 2014). Powell and Wagner (2014), for example, found a high degree of variance in labour productivity in both exporters and non-exporters, and that neither low-productivity exporters nor high-productivity non-exporters are rare. The authors argue that low-productivity firms that can enter the export market do so because they produce high-quality goods. As foreign demand for high-quality products is comparably price-inelastic, high-quality goods that are highly attractive for customers in foreign countries can be sold for a high price, allowing their producers to enter the export market even if less productive. In general, low-productivity exporters tend to serve a small number of countries or trade a small number of goods (Wagner, 2015). For Belgium, for example, Mules and Pisu (2009) show that 18% of firms export to only one destination and these firms tend to show lower labour productivity than those able to reach many countries.

Impact of exporting on productivity

There are two main reasons why firms can increase their productivity through exporting. On the one hand, firms that are lagging behind their domestic or international peers can catch up by learning about existing more efficient methods and processes (**Catching-up** path in ***Figure 1***). On the other hand, firms that are already highly productive can further increase their productivity by discovering new methods and processes and pushing the knowledge and technology frontier (**Innovation** path in ***Figure 1***). Studies on the relationship between exporting and productivity generally show that exporting has the potential to influence both drivers of productivity.

Exporters can learn from international clients and competitors in advanced economies and increase their own productivity. This process is known as learning-by-exporting and has been detected in both emerging and advanced economies. Studies have detected learning by showing that productivity gains are associated with exporting to advanced destinations, as opposed to lower-income countries. This is the case in De Loecker (2007), for example, who found that Slovenian firms exporting solely to low-income regions experience some productivity gains (in terms of total factor productivity), but these gains are lower compared to firms that export to high-income countries. The productivity premium is 20% for firms exporting only to high-income countries and 10% for firms exporting only to low-income countries. Specifically for the UK, Crespi et al. (2008) measured learning directly using data on firms' reported sources of knowledge. They found that compared to domestic-oriented firms, exporters in the UK are more likely to report learning from their clients as opposed to other sources. They also show that firms that learned from clients in the past are more likely to display faster productivity growth. Exporters are found to be 25% more productive (in terms of labour productivity) two years after entering the export market.

Learning-by-exporting allows exporters with initially relatively low levels of productivity to catch up with their more productive domestic or international peers. Another way the literature detects learning by exporting is by considering export effects along initial levels of productivity. Benkovskis et al. (2019), for example, found that exporting boosts the productivity (in terms of total factor productivity) of Estonian and Latvian firms by 35% and 38%, on average, but firms with initially lower productivity levels enjoy larger productivity gains from exporting. They also find that exports of knowledge-intensive services, such as ICT and professional services, result in significantly larger productivity gains than exports of final goods for Latvian and Estonian firms.[26] Focusing on a more advanced economy, Lileeva and Trefler (2010) found that for Canada, the largest gains in labour productivity from exporting are found to be for firms that were initially the least productive (in terms of labour productivity), while the gains decrease progressively and eventually reach zero for firms that were initially the most productive. This is confirmed also in a study on German firms by Powell and Wagner (2014). The authors found that the exporters' labour productivity premium is positive all over the productivity distribution, but firms at the bottom of the distribution enjoy the largest productivity gains from exporting. The exporter premium for German firms is 47% at the bottom of the productivity distribution and approximately 3% at the top.

Because exporters serve larger markets than domestic-oriented firms, they can enjoy higher returns on their investments and are thus incentivised to invest in innovation.[27] This second mechanism refers to the impact of exporting

[26] *In this study, knowledge-intensive services are distinguished from infrastructure-intensive services such as telecommunications, energy and transportation services, which require large physical infrastructure.*
[27] *While access to international markets can also allow firms to increase productivity by increasing capacity and exploit economies of scale in production, this report focuses on changes in productivity that are driven by technological change*

on innovation and the development of more efficient processes that boost productivity. In support of this mechanism, Koch et al. (2021) found that adopting robots raises the firm-level total factor productivity of Spanish firms if, and only if, the robot-adopting firm is also an exporter. Aw et al. (2011) found that there is a virtuous cycle between R&D, exporting and total factor productivity. Both R&D and exporting are found to have a positive effect on a plant's future productivity. This in turn drives more plants to self-select into both activities, contributing to further productivity gains. Overall, they found that an export market expansion increased the R&D participation rate, i.e., the number of firms engaged in R&D, by 4.7%, and this was associated with an increase in mean plant productivity of 5.3%.

Among exporters, an increase in export demand further stimulates innovation and productivity, contributing to the emergence of "export superstars". This mechanism has received less attention in the literature. It is focused on the impact of increased exports among existing exporters, rather than on entering the export market. Mayer et al. (2021), for example, found that export demand shocks prompt French firms to concentrate their export sales on their most successful products. This reallocation of output towards higher-performing products leads to an increase in average labour productivity. More specifically, a 1% increase in export demand increases productivity by at most 3.4% in certain sectors, and by 1.17% on average.[28] In line with the mechanism mentioned above, an expansion in market size, due to increased exports demand, increases the returns to investment and encourages firms to sustain upfront development costs for new productivity-enhancing products and processes (Melitz and Trefler, 2012). When measuring innovation directly, for example by using patenting, Aghion et al. (2022) found that positive export demand shocks induce innovation, measured by patents, but only among the most productive French firms (in terms of labour productivity). The effects take between 2 to 5 years to materialise. The authors point out that the skewed innovation response towards the most productivity firms is likely to generate further increases in market share for the best-performing firms, leading to increases in market concentration. This partly explains the phenomenon of export superstars, which has been documented for exporters in several countries, including Belgium (Muuls and Pisu, 2009), Germany (Wagner 2012) and Norway (Bernard et al. 2014).

3.1.3 Importing and productivity

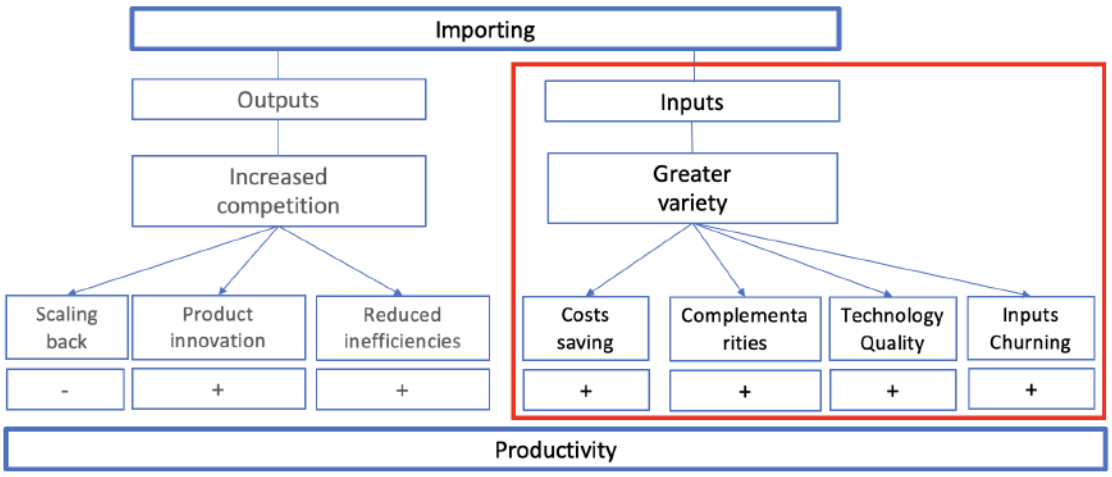
Importing provides firms with access to a wider variety of inputs as well as higher quality inputs, but it can also expose them to international competition in the final goods market. The focus of this section is on the impact of importing on firm productivity, specifically in terms of increasing access to a **greater variety** of intermediate inputs (see the highlighted section of ***Figure* 2**). Access to imported intermediate inputs can positively impact productivity by reducing costs, allowing

and improvements in technical efficiency. Also see Melitz and Trefler (2012) who make the point that the introduction of new products and processes requires substantial upfront investments, which are only profitable for firms if they operate at a large scale; access to larger markets through exporting allows firms to achieve this larger scale.

[28] The largest positive effects are for Wearing Apparel, Wood, Tobacco and Printing and publishing, while the smallest effects are for Coke and refined petroleum product (negative effect), other non-metallic minerals and office machinery.

firms to exploit complementarities between inputs, giving access to higher-quality inputs and their embedded technologies, and allowing firms to experiment with different combinations of products and inputs.

Figure 2: Importing and productivity



Access to cheaper internationally traded intermediate inputs reduces costs of production by lowering input costs and allows firms to devote a greater portion of their expenditures to productive investment. Damijan et al. (2014), for example, found some small but positive effects of a decline in the unit value of imported intermediate goods on the total factor productivity of Slovenian firms. More specifically, a 10% decline in input unit values was associated with a 0.1% increase in productivity. Overall, a 10% increase in imports of intermediate products resulted in an increase of 0.4% increase in productivity.

Access to imported intermediates allows firms to discover input complementarities that can lead to increased productivity. Complementarity implies that the productivity gains that result from using a new combination of inputs exceed the individual contributions of each input. This is because each input has unique characteristics that complement the others, resulting in a synergistic effect that enhances overall productivity. This indicates that inputs cannot be easily substituted and highlights the importance of identifying and utilizing complementary inputs to achieve maximum productivity. Importing also gives access to a larger variety of inputs and allows firms to find a new combination of inputs and discover complementarities. Bas and Strauss-Khan (2015) provide an empirical test for this complementarity effect. They find that importing more varieties of inputs raises the total factor productivity of French firms, no matter where the inputs are imported from. More specifically, the average firm adds four varieties of imported inputs over a 9-year period leading to 2.5% higher productivity. This is also confirmed by Halpern et al. (2009) for a sample of Hungarian firms. The authors found that two-thirds of total factor

productivity gains from importing are due to the variety and complementarity effects, and one-third to the higher quality of foreign-sourced input.[29]

Firms can learn from the quality and the technology embedded in imported intermediate inputs, which have a positive impact on productivity. This positive effect of importing is often associated with imports from advanced economies, as shown by Bas and Strauss-Khan (2015). Importing from advanced economies allows firms to tap into the latest advancements and best practices in their respective industries. This exposure to new and improved technologies and processes can help firms improve their operations, increase their competitiveness, and ultimately boost their total factor productivity.

Access to imported intermediates allows firms to experiment with more combinations of product-inputs, which can lead to higher productivity. Productivity interacts with the choices a firm makes about inputs and products, hence by adjusting the type of inputs used and products produced a firm can increase productivity. This is known as input and product churning, which implies that firms may need to experiment with several types of inputs and products to identify the optimal combination for their specific competencies, and this process leads to higher productivity. Damijan et al., 2014 found that importing is associated with increased product and input churning, which, in turn, has led to total factor productivity gains for Slovenian firms. They do so by looking at the number of inputs that firms add and drop every year and relating this measure to importing and productivity.

3.1.4 Application to the UK policy context

The review of the literature on the link between exporting, importing and productivity holds some potential lessons for leveraging international trade to increase the productivity of UK firms.

On the exporting side, securing high productivity levels is essential for UK firms to be able to enter and retain their position in the export market. Firms that enter the export market are found to be on average between 20% and 40% more productive than domestic oriented firms. This is largely explained by the presence of entry costs to access the export market, such as those related to advertising, distribution, and conforming to foreign regulations, and is supported by international and UK-based evidence. Low-productivity firms can enter the export market only if they can provide high-quality goods, yet the scope in terms of number of products exported and destinations reached for these firms tend to remain limited.

Another relevant finding from the literature indicates that productivity tends to increase with the number of destinations reached. This has important implications for UK firms that used to serve only one major market, i.e., the EU. Firms continuously re-evaluate their position in the export market, the range of products they export and the destinations they reach. Expanding into

[29] *Note that Halpern et al. (2009) did not separate all the four mechanisms presented in Figure 1. For example, it is likely the cost saving and input churning mechanisms are conflated in the "variety and complementarity effect."*

new markets requires a significant number of resources and capabilities, and new barriers to trade with key export markets may make it difficult for less productive UK firms to continue exporting.

Existing studies show that exporting can boost the productivity of firms by facilitating learning-by-exporting. The effects range between a 3% and a 47% increase in productivity and are higher for firms exporting to advanced economies or those displaying initially relatively low levels of productivity.[30] This is confirmed both by the international evidence on advanced economies and UK-based evidence and is in line with the position of the Bank of England (2019). The learning-by-exporting mechanism suggests that UK firms can learn from international clients and competitors in advanced economies and catch up with their more productive domestic or international peers. This is particularly relevant for UK firms that are relatively less productive as exports expose them to new ideas, technologies, and business practices that they would not have encountered otherwise, through their clients and competitors. For example, UK firms may be able to observe the production processes and quality control measures of their competitors and use these observations to improve their processes. Interestingly, the evidence indicates that these benefits are particularly pronounced when exporting to advanced economies. This suggests that policy support, such as export promotion programs, should encourage firms to export to such advanced economies, rather than encourage exporting in general, to maximise the productivity benefits of exporting.

A second mechanism refers to the impact of exporting on innovation, where exporting supports productivity-enhancing innovations by increasing returns to investment through larger scales of operation. When UK firms export to international markets, they can access a larger customer base, and benefit from economies of scale. This, in turn, allows them to invest in research and development and make productivity-enhancing innovations that they would not have considered otherwise. This is particularly important for UK firms that are already highly productive, as exports act as an incentive to innovate and improve further, pushing the knowledge frontier.

Another important channel through which trade can boost the productivity of UK firms is through access to imported intermediates. This is especially important when considering the complexity of modern production processes, the reliance on global supply chains, and the need to promote the competitiveness of UK firms in global markets.

The literature identifies several mechanisms through which importing can increase productivity. First, access to imported intermediates reduces the production costs faced by firms as they can access cheaper internationally traded inputs. This can be especially beneficial for UK firms that operate in

[30] *It should be noted that because of the inherent difficulties in obtaining causal estimates of export effects, these estimates necessarily come with high levels of uncertainty. The wide range in estimates is because the productivity effects of trade vary across types of firms, sectors, and countries. Hence, the context is important when assessing how changes in trade policy may affect productivity.*

industries where the production process requires a variety of specialized inputs or materials that cannot be easily sourced locally, such as the aerospace and pharmaceutical sectors. Second, access to a wider variety of inputs can allow UK firms to find and exploit complementarities in inputs. This means that by combining different inputs in the production process, firms can create value that is greater than the sum of the individual inputs. For example, a UK firm in the automotive industry may be able to find complementary inputs by sourcing specialized materials, such as lightweight composites, from one country, and advanced electronic components from another country. Third, by importing from advanced economies, UK firms can access high-quality inputs that can allow them to tap into the latest technological advancements and best practices in their respective industries. Finally, by accessing new varieties through imports, UK firms can adjust the type of inputs used and products produced. UK firms can experiment with new combinations of inputs to find ways to optimise their production processes, reduce costs, or create new products, which in turn increases productivity, efficiency, and competitiveness.

3.1.5 Challenges with applications to the UK policy context

One of the limitations of the studies reviewed in this section is that, besides a few recent papers, most studies use firm-level data from more than a decade ago, usually from 1995 to 2007. While still informative, the older data may not accurately reflect current economic conditions, technological advancements, and the evolution of global supply chains. Since the UK has left the EU, the experience of UK firms might diverge from that of neighbouring countries. Therefore, some caution must be exercised when generalising the findings to the present day.

Some papers might also be quite context specific. For example, the paper on Slovenia by De Loecker (2007) refers to firms that likely invested in reducing product defects as a prerequisite for exporting to the EU's value chain. Yet, this does not constitute a major concern since the empirical findings that have been identified largely hold across different studies, including those specifically on the UK, which are described in more detail in Section 3.3.

Finally, the studies that have been reviewed employ different measures of productivity with varying levels of rigour. Approaches to measure productivity are mostly driven by data availability, and some approaches might fail to capture pure productivity effects, i.e., improvements in how efficiently inputs are used. While some studies consider more sophisticated measures of productivity, such as total factor productivity (further discussed in the Section 3.4), many rely on simple measures, i.e., revenues per worker (known as labour productivity), due to the lack of additional data. While these studies are still informative, what is considered productivity growth could also be the result of capital accumulation. In addition, even studies that consider measures of total factor productivity might confuse improvements in efficiency (higher output from the same number of inputs) with increases in markups (higher revenues/prices from the same amount of inputs). The fact that positive effects for importing and exporting are

consistently found across studies that use different measures of productivity is reassuring, especially as more recent studies, that have employed more advanced estimation techniques, have led to lower but still positive estimates of the impact of trade on productivity.[31] Yet, while results are qualitatively similar across studies, specific point estimates may differ due to the differences in the methodologies used.

3.1.6 Addressing challenges and overall conclusions

To address the limitations identified above, this study recommends conducting further empirical analyses on trade and productivity using more up-to-date data for the UK, such as the matched firm-trade data that have now become available and are discussed in the Section 3.4. This will allow analysis to consider possible structural and technological changes induced by recent events such as Brexit and the Covid pandemic, especially when it comes to investigating the linkages between trade and productivity across different sectors or regions of the economy. This would address both the limitations regarding the older data used in the reviewed studies, and any differences that may have emerged in the business environment faced by UK firms in comparison to neighbouring countries and other advanced economies. It is also recommended that testing of the robustness of the results is conducted using alternative measures of productivity and especially, if possible, using more sophisticated measures of productivity, as described below.[32]

Overall, the literature review has provided consistent evidence pointing towards significant benefits from both importing and exporting in terms of productivity growth. Trade can increase the productivity of UK firms in two ways. Firstly, through a "learning-by-exporting" process, where UK firms can learn from international clients and competitors and catch up with more productive international peers, especially when exporting to advanced economies. Secondly, through the impact of exporting on innovation, where exporting supports productivity-enhancing innovations by increasing the scale of operations. Access to imported intermediates is another important channel through which trade can boost productivity, as it can reduce production costs, allow firms to access higher-quality inputs, find and exploit new complementarities in inputs, and experiment with new combinations of inputs to optimise production processes.

[31] *These techniques allow researchers to separate pure productivity effects from price effects. See for example De Loecker (2011) and De Locker (2013) described below.*
[32] *Section 3.4 discusses in more detail what analyses can be done and what studies can be replicated using more recent matched firm-trade data for the UK.*

3.2 Performance of strictly importing against strictly exporting firms and trade frictions

3.2.1 Headline Description

This section has two parts, one regarding the linkages between importing, exporting and productivity, and a second part regarding the impact of trade frictions on productivity.

Firms that manage to engage in both importing and exporting (two-way trade) tend to have a larger productivity advantage, consistent with higher entry costs to two-way trade. The review of the linkages between importing, exporting and productivity has found that there are some commonalities in terms of entry costs between importing and exporting. Studies show that firms engaged in importing are more likely to enter export markets due to the common investments they have already made in acquiring the necessary resources and capabilities for international trade.[33]. There is also evidence that jointly exporting and importing confers additional productivity gains to firms, after entry, compared to engaging in one of the two activities only.

Barriers to exporting to key foreign markets can increase the costs and complexity of exporting for UK firms and weaken the complementarity between importing and exporting. That is, firms can no longer use their experience from the importing process to help them with exporting, as exporting now faces very different challenges from importing, for example due to different regulatory requirements.[34] Ultimately, this could imply the exit from the export market for some UK firms.

The review also finds that importing can have both direct and indirect effects, through productivity, on exporting. On one hand, import-induced productivity gains can allow firms to bear the entry costs of exporting and increase the chances of surviving in the competitive export market. On the other hand, importing can have direct effects on exporting as it can help to improve the quality of exported products through input-product complementarities, and by facilitating knowledge and technology transfer. Importing can also induce cost savings that can boost the return from exporting.

Finally, the review of the literature on import disruptions has highlighted the negative impact that supply chain disruptions have on the impacted firms' production activities, and subsequently on their domestic sales and exports, which tend to significantly decline. These declines in turn tend to lower firm-level productivity. Accordingly, the review recommends that UK policymakers should refrain from imposing unnecessary restrictions on supply chains through the use of tariffs on intermediate inputs and should instead aim to lower such tariffs, which is likely to significantly increase UK firm-level

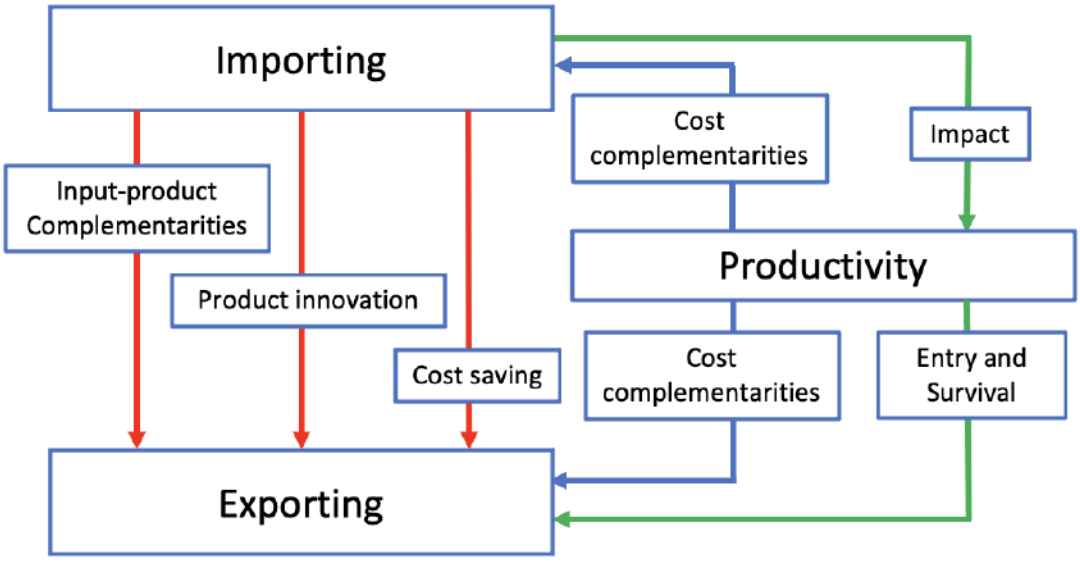
[33] *This literature focuses on importing and exporting in general, rather than importing from and exporting to the same country.*
[34] *For example, if importing and exporting regulation diverge, the knowledge acquired through importing might not be used for exporting. Ultimately, this could imply the exit from both exporting and importing for some UK firms.*

productivity, subject to the caveat that existing evidence may not be fully relevant to the UK (see Section 3.2.5).

3.2.2 Importing-exporting linkages

Importing can be associated with exporting either because some of the entry costs are shared between the two activities (cost complementarities, blue arrows in ***Figure 3***), or because importing, directly or indirectly, increases the likelihood of exporting or surviving in the export market (green and red pathways in ***Figure 3***).

Figure 3: Importing-Exporting linkages



Cost complementarities

Sunk cost complementarities refer to the fact that once a firm incurs entry costs related to importing, such as investing in new supply chains or training employees to work with new inputs in the case of importing, it may find it easier to also start exporting.[35] This ultimately relates to productivity, since the presence of entry costs is one of the main reasons why highly productive firms are more likely to trade internationally.

If entry costs are shared between importing and exporting activities, when firms begin to sell outputs or purchase inputs from abroad, they become more likely to start operating internationally at the other end of the market. Kasahara and Lapham (2013) extend Melitz (2003)'s model to incorporate imports of intermediate inputs and provide some useful intuitions. There can be two possibilities. On the one hand, if there are complementarities in terms of entry costs between importing and exporting, i.e., some entry costs are common

[35] *Entry costs are also referred to as sunk costs, since once they are incurred, they cannot be recovered. For example, these could include expenses such as market research and legal fees, which are incurred upfront and cannot be recovered if the plan to export is then abandoned.*

to the two activities, firms already engaged in one-way trade would be more likely to become two-way traders. This, for example, refers to a situation where a firm that has incurred costs related to importing, such as investing in logistic infrastructure like warehouses, transportation vehicles, and customs clearance procedures, found it easier to also start exporting. On the other hand, if firms that engage in both importing and exporting activities need to bear higher costs of entry, then only the most productive firms will self-select into two-way trade. This is the case, for example, if firms must comply with additional international regulations such as customs procedures for exporting or need to coordinate more complex supply chains by entering the export market.

Empirical evidence points towards the presence of some complementarities in entry costs between importing and exporting. This is demonstrated by the fact that importers are more likely to start exporting, implying that some entry costs are shared between the two activities. Mules and Pisu (2009), for example, found that the past importing status of Belgium firms increases participation in the export market. More specifically, importers are 42% more likely to become exporters. Haller (2012), for example, divides Irish firms into six mutually exclusive categories: firms that do no trade overseas, firms that export only, firms that import only, firms that export and import, domestic firms that engage in intra-firm trade[36], and foreign-owned firms that engage in intra-firm trade. She finds that Irish firms that import are as productive as those engaged in both importing and exporting.

But not all entry costs are shared between importing and exporting, and firms that can engage in two-way trade tend to have a larger productivity advantage. This result implies that only some of the costs are common between the two activities, and exporting can still bear additional costs of entry. This is shown by observing that firms engaged in two-way trade are more productive than one-way traders. Castellani et al. (2010), for example, showed that Italian firms that both export and import are larger and more productive (in terms of labour productivity) than those engaged in one of the two activities only. For Belgium, Muuls and Pisu (2009) found that two-way traders have the largest labour productivity advantage (21%) compared to importers and exporters only (9% and 6%, respectively). Similarly, for Germany, Vogel, and Wagner (2009) find that two-way traders enjoy a labour productivity premium of 9% compared to 4% for exporter only and 3% for importer only. For the UK, Breinlich and Criscuolu (2011) focus on trade in services and find that the productivity premium for firms that both import and export services are higher (10%) than if firms that only import services (4%). This also implies that entering the export market for services bears additional costs. Overall, the literature agrees that studies that did not consider the role of importing might have overstated the productivity advantage of exporters by not considering the role of imports.

Indirect effect of importing on exporting through productivity

[36] *Intra-firm trade is defined as international trade between subsidiaries of the same multinational corporation.*

Above, the study discussed separately how importing can increase productivity and how more productive firms are more likely to become exporters. However, there were no direct links drawn between the two activities.[37] By contrast, the studies reviewed in this section have considered the simultaneous role of importing and exporting and their relationship with productivity.

Importing increases the likelihood of exporting by raising firm productivity. Import-induced productivity gains can allow firms to bear the entry costs of exporting (Entry into exporting) and increase the chances of surviving in the competitive export market (Survival in the export market), see the green pathway in ***Figure 3***. In this section, the focus is explicitly on those studies that have attempted to establish a link between past importing, current productivity levels and future export choices. Considering a group of 27 Eastern European countries, Aristei et al. (2013) found that firm importing activity has a positive effect on foreign sales. More specifically, importers are 47% more likely to enter the export market. They argue that this effect is due to importing contributing to increased firm labour productivity, which in turn fosters exporting. They demonstrate this by showing that the positive effect of past importing on current exporting vanishes once they account for the productivity-enhancing effects of imports. Bas and Strauss-Khan adopt a similar approach using French data. They show that the impact of past importing inputs on exporting is reduced from 6.5% to 4.7% once productivity effects are accounted for. The gap reflects the effect of importing on exporting, through increased productivity.[38]

Jointly exporting and importing confers additional productivity advantages to firms. The related literature has looked at the impact of two-way trade, as opposed to one-way trade, on productivity. Haller (2012), using data on Irish firms, explores additional interactions between importing, exporting and total factor productivity. When looking at changes in trading status over time, the author finds that jointly exporting and importing confers additional advantages to the firms involved. The productivity premium for exporters accrues only to firms that both export and import or that engage in intra-firm trade. Specifically for the UK, Harris and Moffat (2015) also found that manufacturing UK firms that both exported and imported experienced significant total factor productivity gains (9%) while involvement in only one of these activities was not sufficient to boost productivity. These results suggest that assisting firms to enter the export market might not be sufficient. Support with identifying suppliers abroad is equally important for improvements in firm productivity.

Direct effect of importing on exporting

Importing can have direct effects on exporting by improving the quality of exported products through input-product complementarities, and by facilitating knowledge and technology transfer. Evidence of a direct effect of importing on exporting is limited and has relied on estimating the effect of past

[37] *This is because estimates from studies that used different contexts are not directly comparable. In this section, the review looks at studies that investigate importing and exporting within the same context.*
[38] *The fact that the impact remains positive and does not vanish completely is used to confirm the presence of direct effects, as further explained below.*

importing on exporting after accounting for productivity effects. The fact that importing maintains explanatory power, after the indirect productivity channel has been accounted for, is suggestive of the presence of direct effects of importing on exporting. Bas and Strauss-Kahn (2010) find that a higher diversification and an increased number of imported varieties affect export scope (i.e., the number of exported varieties) directly, i.e., beyond any effect on total factor productivity. After accounting for productivity effects, they found that a 10% increase in the number of imported input varieties by French firms increases the number of exported products by 10%. This applies to both imports from low and high-income economies. The authors attribute the effects to two main mechanisms, although they do not provide direct testing. First, there are complementarities between imported inputs/markets and exported products/markets. Second, importing allows technology transfer, which leads to product innovation. Regarding the latter effect, the authors argue that France has sufficient absorptive capacity to be able to transfer the technological content of imports, and this is likely to also be the case for UK firms.

Importing can have direct effects on exporting by inducing cost savings that can boost the return from exporting. Evidence on this mechanism is also limited. Lo Turco and Maggioni (2011), for example, show evidence supporting the cost-saving effect for Italy. They find that a higher share of imports from low-income countries, which they assume to be motivated by the desire to lower costs, has a positive effect on the propensity to export of Italian firms, while imports from high-income countries have no effect. This can be explained by the fact that Italian exports rely on traditional products that have a low technological content and face fierce competition from emerging economies. In this context, firms that can source cheaper inputs abroad are more likely to survive in the competitive export market. However, this is less likely to apply to the UK context where exports rely more heavily on advanced technologies, which limits the opportunity to save costs by sourcing inputs from low-income countries.

3.2.3 Trade frictions and productivity

This section will review studies about the link between importing, exporting and productivity and the consequences of disruptions to importing in this context. That is, the object of interest are firms that import intermediate inputs intending to use such imports to produce exports. The review aims to understand the consequences of disruptions to imports on the subsequent exports and learn about the resulting productivity effects.

Having reviewed the literature, this research question can be only partially answered based on existing evidence. There is some literature available discussing the connection between importing and exporting and how disruptions to importing affect firm-level export performance, but existing studies do not connect such disruptions to firm-level productivity.

The negative effect of supply chain disruptions on domestic sales and exports and the resulting productivity effects

To begin with, some studies have looked at the consequences of the Covid pandemic on supply chains. For example, Joussier, Martin and Mejean (2022) analyse the consequences of disruptions to the imports of intermediate inputs from China as a result of the early 2020 Covid lockdown in China. They find that French firms sourcing inputs from China experienced a 7.4% drop in imports between February and June 2020 relative to firms that did not source from China. The exposed firms further experienced a 5.5% drop in domestic sales and a 5% drop in exports compared to non-exposed firms. The drop in export sales seems to have been primarily driven by firms temporarily exiting non-core markets (defined as markets that were not the main destination of exports in the five months before the Covid supply shock). Joussier and Mejean also look at ways of mitigating the negative impact of the supply chain shock caused by Covid and find that greater ex-ante diversification of input sources did not mitigate the negative impact of the Covid shock but that holding higher inventories did.[39]

Note that the ineffectiveness of input source diversification does not contradict the finding by Bas and Strauss-Kahn (2010) discussed earlier, that higher diversification and an increased number of imported varieties affect export scope (i.e., the number of exported varieties). This is because Bas and Strauss Kahn look at the number of exported varieties rather than overall exports as Joussier, Martin and Mejean. In addition, the latter authors look at the reaction to a supply chain shock, whereas Bas and Strauss Kahn look at the general relationship between input source diversification and exports. Put differently, while diversification might help with exporting a greater number of products in the long run, it will not protect a firm against supply chain disruptions.

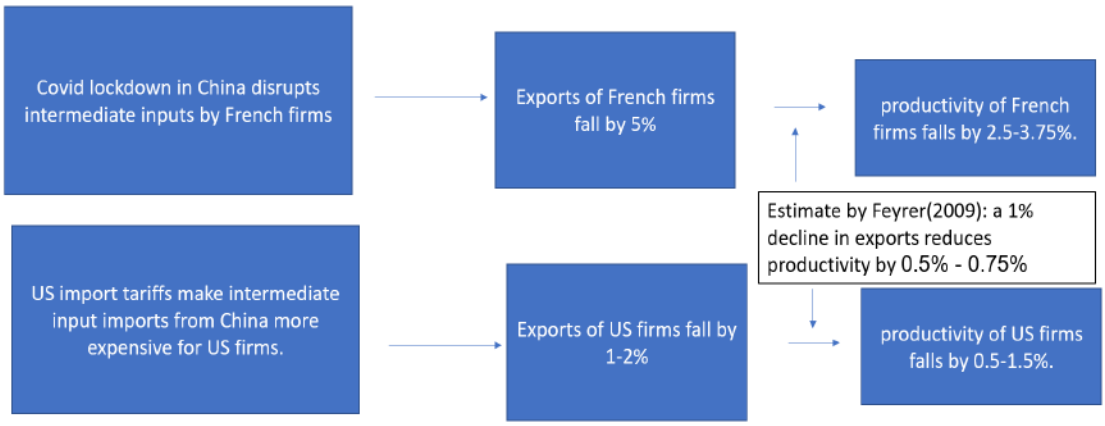
Handley et al. (2020) study the **consequences of US import tariffs imposed by the Trump administration in 2018-2019 on the export performance of US firms which sourced intermediate inputs from China in the pre-tariff-war period**. To begin with, they establish that for the average affected firm, the increase in the costs of intermediate inputs caused by the tariffs was $900 per worker. Second, they also show that the most exposed products had relatively lower export growth in 2018-2019, with larger effects in 2019. Specifically, products with average exposure to the import tariffs experienced 1% slower export growth than non-exposed products. For products with high exposure (two standard deviations of the export exposure measure), the slowdown in export growth was 2%. Put differently, the tariffs on intermediate inputs imposed by the Trump administration lowered US exports in products with average exposure to the tariffs by 1% and by 2% for highly exposed products. For comparison, the decline for the average product is the same that would have resulted from the imposition of a 2% ad valorem tariff on US exports of that product; the corresponding ad valorem tariff for highly exposed products would have been 4%.

[39] *Specifically, Joussier and Mejean's findings suggest that firms could have completely eliminated the impact of the Covid supply chain shock by holding a sufficient amount of inventories, where sufficient in this context means an inventory to sales ratio that is among the top 20% of the firms of the industry the firm belongs to.*

While Joussier and Mejean (2022) and Handley et al (2020) estimate the impact of supply chain disruptions on exports, they do not directly link this decline to the productivity of the exporting firms.

However, **it is possible to carry out a rough back-of-the-envelope calculation of the resulting productivity effects by making use of existing estimates from the literature on the link between trade and economic growth.** Specifically, Feyrer (2009) finds that a 1% decline in trade reduces GDP per capita by between 0.5% and 0.75%. Since GDP per capita is closely related to a standard measure of productivity, value added per worker, it seems reasonable to assume a similar link between exporting and firm-level productivity.[40] ***Figure 4*** illustrates the resulting calculations graphically. Using the estimates from Feyrer (2009), this would imply that the supply chain disruption due to Covid, which reduced exports of French firms by 5%, would have decreased the productivity of these firms by between 2.5% and 3.75%. Likewise, the Trump administration tariffs, which reduced exports by US firms by between 1% and 2%, would have reduced the productivity of these exporters by between 0.5% and 1.5%.[41]

Figure 4: The productivity impact of supply chain disruptions



Natural disasters and supply chain disruptions

Also related to the topic of supply chain disruptions is a growing literature on supply chain disruptions caused by natural disasters such as the 2011 Great East-Japan earthquake. Again, this literature does not look at the productivity impact of supply chain disruptions, nor the link between supply chain disruptions

[40] Note, however, that Feyrer (2009) looks at overall trade (an average of imports and exports), not just exports. Hence, our calculations are only valid under the assumption that the productivity effects of changes in total trade are the same as those of changes in exports. Furthermore, it is assumed that the productivity effects for individual firms are the same as the economy-wide effects Feyrer estimates.

[41] In a recent report, Bank of England (2019) also makes use of estimates by Feyrer, but these refer to another paper (Feyrer, 2009b) which estimates a slightly lower impact of trade on per capita income (a 1% decrease in trade lowers per capita income by 0.25%). Using this alternative estimate, the Trump administration tariffs would have been estimated to reduce the productivity of US firms by between 0.25% and 0.5%; and the early 2020 Covid lockdown would have reduced the productivity of French firms by 1.25%.

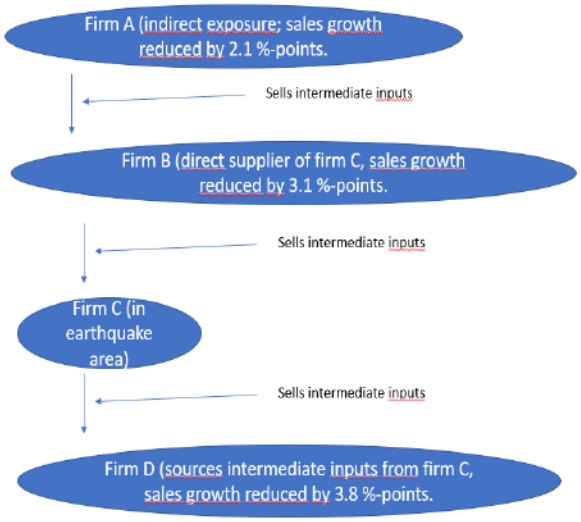
and exporting. Instead, it tends to analyse alternative indicators of firm-level performance such as domestic sales or stock prices.

The 2011 Japanese earthquake hurt the sales of firms along the supply chain

For example, in what is probably the most influential paper in this literature, Carvalho et al. (2021) estimate the effect of the 2011 Japanese earthquake on Japanese firms that had suppliers or customers in the areas affected by the earthquake. They find that firms with disaster-hit suppliers observed a 3.8 percentage points reduction in their sales growth rate in the year after the earthquake, and firms with disaster-hit customers saw a 3.1 percentage points decline in their sales growth rate. They also find indirect higher-order effects on firms further down the supply chain (e.g., suppliers of firms with disaster-hit customers also saw a 2.1 percentage point decline in their sales growth rates).

Figure 5 illustrates these supply chain relationships graphically. Firm C is a firm in the earthquake area and was thus directly affected by the earthquake. Firms A, B and D were not directly affected but are indirectly exposed through their supply chain links with firm C. Firm B is a direct supplier of firm C and thus has a first-order supply chain exposure. According to the findings by Carvalho et al., it will experience a reduction in its sales growth rate of 3.1 percentage points in the year after the earthquake. Firm D also has a first-order supply chain exposure, because it sources intermediate inputs from an earthquake-stricken firm. According to the findings by Carvalho et al., it will experience a reduction in its sales growth rate of 3.8 percentage points in the year after the earthquake. By contrast, firm A only has a higher-order exposure to the earthquake, because it sells intermediate inputs to firm B, which in turn sells to firm C, which was directly affected by the earthquake. According to the findings by Carvalho et al. This second-order exposure will reduce firm A's sales growth rate as well, but only by 2.1 percentage points.

Figure 5: Illustration of findings from Carvalho et al. (2021)



A study closely related to Carvalho et al. (2021) is Inoue and Todo (2022), who use an agent-based model to simulate the effects of supply-chain disruptions on the Japanese economy. They find that disruptions of imports of intermediate inputs (e.g., those from China caused by the Covid pandemic) only cause a negligible fall in production in the short run, because firms can fall back on stocks of intermediate inputs. As the duration of the supply shock increases, however, the estimated production declines rapidly increase, reaching 2.9% after four weeks and 26% after two months.[42]

The earthquake also affected US-based Japanese multinationals

Boehm et al. (2019) study the impact of the 2011 Japanese earthquake on Japanese Multinationals in the US, which source intermediate inputs from their home country (Japan). They find that imports from Japan by US-based Japanese multinationals fell substantially after the earthquake and that the output of these multinationals fell by the same magnitude as imports from Japan, indicating poor substitutability between inputs from Japan and domestic (U.S.) inputs.

Supply chain disruptions also lower stock market returns

Finally, Hendricks and Singhal (2009) estimate the impact of announcements of supply chain disruptions on the long-run stock market performance and stock price volatility of the affected U.S. publicly listed firms. For a sample of U.S. firms listed on NYSE, AMEX, and NASDAQ, they find that during the period 1989-2000, firms that had to announce supply chain disruptions experienced lower abnormal returns (-40%) and increased stock price volatility (a measure of equity risk) in the year after the announcement.

Lowering intermediate input tariffs increases productivity

The final set of papers looks at the consequences of liberalising the imports of intermediate inputs on productivity. This literature does not look at exporting, but instead analyses the productivity consequences of removing an obstacle to importing. The consensus in this literature is that reducing barriers to the imports of intermediate inputs increases firm-level productivity. For example, Amiti and Konings (2007) study the effects of reductions in tariffs on final and intermediate goods in the context of the trade liberalisation implemented by Indonesia in 1995-2001. They find that a 10-percentage point fall in input tariffs led to a productivity gain of 12 per cent for firms that import their inputs; for comparison, the productivity gain associated with reductions in output tariffs (which leads to greater product market competition) was substantially smaller; here, a 10-percentage point reduction only led to a productivity increase of between 1 and 6 per cent, depending on the estimation technique.

Input tariff reductions work best in conjunction with other policy changes

[42] *Note that one important shortcoming of Inoue and Todo (2022) is that they use simulations, rather than observing actual production declines as in Carvalho et al. (2021). They also rely on an agent-based model which does not allow for price reactions, which could soften production declines, as resources get redirected to their most productive use through price signals.*

Likewise, Topalova and Khandelwal (2011) use India's 1991 trade liberalization to study the effects of reductions in output and intermediate input tariffs on firm-level productivity. They find that reductions in output and intermediate input tariffs both increase firm-level productivity, but that intermediate input tariff reductions have larger effects. They also show that the productivity-enhancing effects are strongest when tariff liberalization is accompanied by other industrial policy reforms such as FDI liberalisation and delicensing.

3.2.4 Application to the UK policy context

As discussed previously, this part of the review consists of two parts, one regarding the linkages between importing, exporting and productivity, and a second part regarding the impact of trade frictions on productivity. The empirical evidence for both parts discussed above yields interesting insights and provides a number of policy implications for the UK context.

The review of the linkages between importing, exporting and productivity has found that there are some partial complementarities in terms of entry costs between importing and exporting. Studies show that firms engaged in importing are more likely to enter the export markets due to the common investments they have already made in acquiring the necessary resources and capabilities for international trade. Barriers to exporting to key foreign markets increase the costs and complexity of exporting for UK firms, potentially making it more difficult for them to enter or remain in the export market. This can reduce the benefits of importing for these firms as well, as the complementarity between importing and exporting is weakened. For example, if importing and exporting regulation diverge, the knowledge acquired through importing might not be used for exporting. Ultimately, this could imply the exit from both exporting and importing for some UK firms.

The evidence also shows that importing can boost exports both directly and indirectly. Indirectly, importing can increase firms' productivity, which in turn can help them cover the entry costs associated with exporting and increase the chances of success in competitive export markets. Importing can also have direct effects on exporting, as it can result in product innovations and increased product quality through the transfer of technology and knowledge embedded in imports. Hence, securing access to imported intermediates is not only an engine for productivity growth, but also a critical factor for enhancing the UK's competitiveness in global markets.

Regarding the impact of trade frictions on productivity, the literature shows that supply chain disruptions tend to significantly impact the ability of firms to import the intermediate inputs necessary for their production activities.[43] This in turn will impact firms' domestic sales and exports, with subsequent negative impacts on firm productivity. These negative effects tend to increase dramatically with the duration of the supply chain disruption, as firms

[43] *In line with the brief for this literature review, the following conclusions and recommendations apply to supply chain disruptions only. Other types of shocks to firms' production processes have not been considered.*

can cover short-run disruptions to input supplies from inventories, but not longer-lasting ones.

The literature also documents some detrimental impacts of supply chain disruptions on firms' financial performance, as reflected in the strongly negative stock price reactions of firms exposed to supply chain disruptions (-40% in the year after the disruption).

Finally, **the literature reviewed highlights the role of policy decisions in disrupting supply chains**, such as the imposition of tariffs on intermediate inputs by the Trump administration in 2018-2019. Relatedly, the literature also suggests that **lowering tariffs on intermediate inputs will be very beneficial for the productivity of the liberalising country**. Thus, the overall message arising from the literature reviewed is that policymakers should refrain from creating unnecessary disruptions to supply chains through the imposition of tariffs on intermediate inputs and instead undertake steps to lower such tariffs. Interestingly, the reviewed literature also suggests that the benefits from reducing intermediate input tariffs can be further enhanced if tariff liberalisation is accompanied by other policy reforms (such as FDI liberalisation).

3.2.5 Challenges with applications to the UK policy context

One of the limitations of studies that focus on both importing and exporting activities is that they tend to be descriptive and less focused on causal identification. In addition, by considering different types of firms (some papers consider up to 6 categories of firms based on their level of internationalisation), they tend to produce a range of different results which are difficult to reconcile under an overarching framework. There is also a gap in terms of evidence on the direct links between importing and exporting. Finally, the majority of studies do not explore differences across sectors, which could further the understanding of the specific mechanisms at work.

Another key challenge in applying the insights from the literature reviewed to a UK policy context is that not all available evidence seems applicable to the UK. While the evidence on the impact of supply chain disruptions is for developed economies such as the US, Japan and France, the literature on the effects of reducing intermediate input tariffs is exclusively for economies with very different structures from the UK (India and Indonesia) and as such is unlikely to be directly applicable to the UK context.[44]

3.2.6 Addressing challenges and overall conclusions

To address the limitations identified above, this study recommends conducting further empirical analyses using more up-to-date data for the UK. Recent trends in trade and productivity can be explored by categorising UK firms based on their level of internationalisation, distinguishing between one-way (firms that only export or only import) and two-way traders (firms that both import

[44] *Note that while existing evidence on supply chain disruptions is applicable to the UK, further research might still be beneficial here as well, in the sense that it could shed light on the effects of recent disruptions to UK supply chains, such as those caused by the Covid pandemic.*

and export). It is also recommended to conduct additional heterogeneity analysis to explore differential impacts across firms with different characteristics or belonging to different regions or sectors. This would help to further understand the specific mechanisms that are at work for UK firms. This is especially important given the changes brought about by the UK's departure from the EU. These analyses, for example, could help shed light on the extent to which the complementarities between importing and exporting, discussed above, have been affected by the recent barriers to trade with the EU and on whether the ability of the UK firms to compete in the global marketplace has been compromised by disruptions to imports.

Secondly, overcoming the challenge of applying existing insights on the reduction of tariffs on intermediate inputs to a UK context will require additional work to be carried out. Below, two possibilities of how this could be done in a UK context are described:

1) A first option would be to use the reductions in tariffs agreed to in the Uruguay round of trade negotiations (concluded in 1995), which led to reductions in the tariffs charged on imports into the European Union, of which the UK was still a member at the time. Data on these tariff reductions could be obtained from standard sources for EU tariffs (e.g., the EU Commission's TARIC database). These output tariffs could then be used to compute the implied reductions in intermediate input tariffs using the methodology outlined in Amiti and Konings (2007) and data from UK input-output tables. The resulting measure of intermediate input tariffs could then be used as a regressor in a regression with the productivity of UK importers as the dependent variable. While it is unlikely that UK firm-level data will contain as detailed information on intermediate input usage as the Indonesian data used by Amiti and Konings, it should be possible to use the information on the importers' industry to link UK firm-level data (e.g., from the Annual Business survey) to the newly constructed data on intermediate input tariffs.

2) A second option would be to use variation in intermediate input tariffs created by temporary trade protection, in the spirit of Conconi et al. (2022) who investigate the consequences of U.S. anti-dumping duties on U.S. manufacturing firms. Similar variation in the UK should be available because of the UK's membership of the EU until recently, given that the EU was (and is) an active user of antidumping duties. Specifically, one could use changes in EU import tariffs to again compute the resulting changes in intermediate input tariffs using the methodology outlined in Amiti and Konings (2007) and data from UK input-output tables. The resulting tariff measure could then again be used in a regression of UK firm-level productivity on intermediate input tariffs, as outlined for option 1 above.

Both approaches have strengths and weaknesses in terms of reliability and feasibility. Regarding reliability, approach 1 is probably more likely to yield

reliable results. This is because anti-dumping duties tend to be systematically imposed to protect declining and underperforming industries and these tend to be industries that suffer from declining productivity. Hence, the analysis proposed in 2) would risk picking up these underlying trends and erroneously conclude that intermediate input tariff reductions lead to productivity declines, or at least would understate potential productivity gains. In principle, a similar problem could affect approach 1), because countries might have been reluctant to liberalise trade in declining industries, leading to a similar concern as with approach 2). However, because tariff reductions in the Uruguay round were part of a much wider package of liberalisation initiatives (such as the liberalisation of services trade (the GATS agreement) or the protection of intellectual property rights (the TRIPS agreement), it seems less likely that the negotiating parties were able to tailor tariff reductions in individual industries to protect declining industries. As such, approach 1) would be less likely to suffer from the problem of underestimating the productivity gains from intermediate input tariff liberalisation.

Having said that, approach 1) might suffer from the problem that the tariff reductions implemented as part of the Uruguay round might not have been substantial enough to yield clear-cut estimation results. This is because manufacturing trade had already been liberalised in many of the previous GATT rounds. Put differently, it could be that the reduction of intermediate input tariffs might not vary substantially across sectors and firms, making it difficult to attribute productivity gains to these reductions with a high degree of certainty. By contrast, anti-dumping tariffs are usually quite substantial and thus this problem will only arise to a lesser degree.[45]

So overall, there are clear trade-offs involved between the two approaches. However, on balance the recommendation is to attempt approach 1) first, given that results from this approach are likely to be more reliable. Only if approach 1) should turn out to be infeasible should approach 2) be attempted instead.

Should this additional work confirm the role that reductions in intermediate input tariffs can play in improving productivity in a UK context, the resulting implication for UK policies aimed at improving the productivity of UK firms is straightforward. Policymakers should refrain from imposing tariffs on intermediate imports (e.g., through anti-dumping duties) and instead try to lower these tariffs.

So overall, the review of the literature on import disruptions has identified two potential levers for shaping the U.K.'s trade environment in ways that are beneficial for the productivity of UK firms. First, while policymakers will not be able to prevent all supply chain disruptions, many of which are due to naturally occurring disasters (such as earthquakes or the Covid pandemic), they should refrain from imposing additional restrictions on supply chains through the

[45] *There is also the additional issue for approach 1 that the tariff reductions implemented as part of the Uruguay round coincided with various reforms to the domestic sectors and subsidy regimes of the liberalising countries, as well as fluctuation in important exchange rates (such as the £/euro/deutsche mark exchange rates). These are all potential confounders, which a study relying on tariff variations resulting from the Uruguay round would need to consider.*

use of tariffs on intermediate inputs. Second, productivity might be significantly enhanced by actively lowering such tariffs.

3.3 Impact of changes in trade on productivity and the UK economy and businesses

3.3.1 Headline Description

This section covers the impact of changes in trade on productivity in the UK context. It also covers the consequent impact of trade-related productivity changes on the UK economy, particularly in terms of both employment and wages.

Data issues have rendered simple statements like "if trade goes up or down by x% then UK productivity increases/decreases by y%" difficult to infer.

Nevertheless, the existing literature has revealed that productive UK firms are more likely to engage in international trade, to begin with. This implies that productive UK firms may be more receptive to trade promotion activities undertaken by DBT and other organisations.

There is also good evidence that changes in trade improve UK productivity. This occurs through market share reallocation (more productive firms growing at the expense of less productive ones), but also through within-company productivity growth that results from learning-by-exporting, innovation, and access to imported intermediaries, with non-trading firms also benefiting via spillovers from exporting firms.

Research suggests that engaging in international trade is associated with a *subsequent* increase in firm-level productivity that ranges from 3%-22%. As a best central estimate derived from the most recent causal analysis, engaging in importing and exporting is associated with a subsequent increase in TFP of 6.7% amongst UK firms[46]. These figures are derived from UK-based studies that attempt to isolate the causal effects of engaging with international trade; they should not be compared with the 20-40% range referred to above which measures the correlative relationship between trade and productivity.

Productivity gains seem most pronounced in UK firms that import and export as opposed to UK firms that engage in just one of these activities. This implies that successful and comprehensive trade promotion, which focuses on imports as well as exports, can foster productivity improvements amongst UK businesses. In turn, trade-related productivity growth is likely to have a net positive effect on employment and mean employee compensation.

No research has attempted to isolate trade-related productivity changes from other trade effects. But improved efficiency has likely fostered an aggregate rise in labour demand through a range of induced effects. These

[46] *The central estimate of 6.7% is derived from Harris and Moffat (2015). This figure is cited as it is drawn from relatively recent research (2011/12) that deploys robust econometrics to control for endogeneity in assessing the effects of importing and exporting on TFP amongst UK firms. Other figures used to compile the range pertain to importing or exporting and/or older time periods.*

include an increase in employee mean compensation that is broadly equal to any productivity growth. This implies that trade promotion activities and subsequent productivity gains are likely to exhibit a net-positive effect on UK employment and wages.

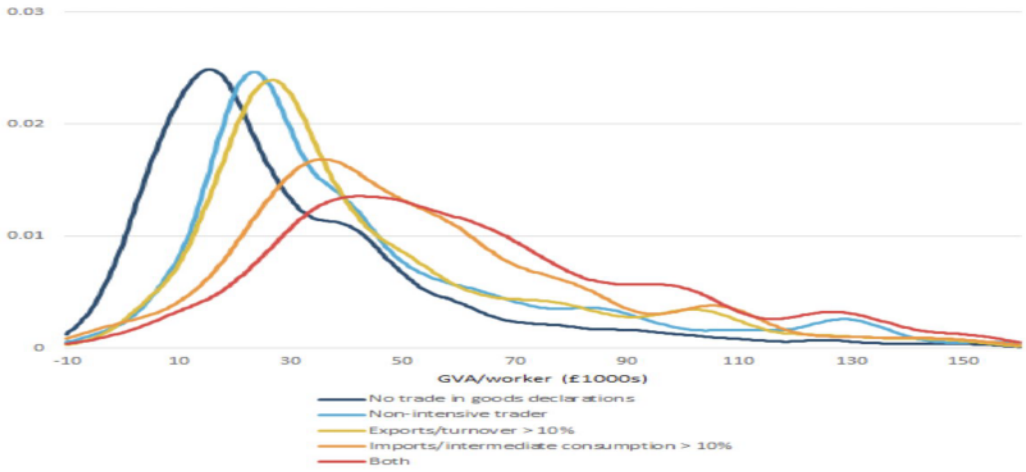
Drawing conclusions on UK regions and nations has also not been possible due to the absence of research on trade and productivity that makes sub-national distinctions. This represents a potential area of future study.

3.3.2 Quantifying the impact of changes in trade on productivity in the UK

This section focuses on literature quantifying the impact of changes in trade on productivity in the UK.

There is good evidence that UK firms engaged in international trade have higher labour productivity than non-trading firms. ESCoE (2018), summarised by ONS (2018), has conducted one of the most recent analyses on the impact of changes in trade on productivity in the UK. Descriptive statistics and a simple linear regression are deployed to assess the link between productivity and goods trader status for British businesses between 2008 and 2016. The approximate gross value added per worker is modelled as a function of exporter/importer status and various control variables. Results show that businesses which reported goods exports or goods imports were 21% and 20% more productive, respectively, compared with businesses which did not trade. Moreover, the productivity premia associated with trading with non-EU markets were considerably larger than those associated with EU trade (14.7% and 16.3% larger for imports and exports, respectively), suggesting that lower productivity businesses found it easier to access EU markets than non-EU markets.

Figure 6: Distribution of labour productivity by trader status, employment weighted, 2016



Note: Based on the ABS // Source: ESCoE (2018)

However, it is difficult to account for self-selection. In other words, it is difficult to understand whether UK firms that trade are more productive to begin with or become more productive with the trading process. Indeed, one drawback

of the ESCoE study is that the authors do not convincingly account for endogeneity bias in their specifications. That is, they do not control for the fact that productive firms are more inclined to trade to begin with.

Other research provides better causal evidence for trade leading to productivity gains among UK firms. For instance, Son (2021) uses matched UK administrative data to examine how global trade expansion from 2002-2011 affected R&D investment amongst British firms. Although not a measure of productivity per se, R&D investment is a major source of long-term productivity growth. Firm-level R&D expenditure is modelled as a function of Chinese import competition, firm-level export demand and various controls. Son found that UK firms' R&D spending fell by approximately four per cent for every percentage point rise in exposure to Chinese import competition. Conversely, UK firms' R&D spending increased by around six per cent for every one-unit increase in export demand. More labour-productive firms that had already entered the export market were found to be better poised to take advantage of increases in foreign demand.

Looking at total factor productivity (TFP), Harris & Moffat (2015) use plant-level data and propensity score matching to estimate the effects of exporting and importing goods and services amongst UK plants between 2011 and 2012. They found that plants in manufacturing, services, wholesale, and retail that either import *or* export produced up to 5% more than equivalent non-trading plants, controlling for employment, intermediate inputs, capital stock and other variables.

Furthermore, Harris and Moffat found that plants in manufacturing, services, wholesale, and retail that import *and* export produce more (8.8%, 5.9% and 6.3%, respectively) than equivalent non-trading plants, controlling inputs and other variables.

In one of the most convincing studies in this space, Harris and Li (2012) found that UK firms that export enjoyed a 22% increase in TFP during the first year of entry, while firms exiting overseas markets experienced a 15% decline in TFP. Specifically, Harris and Li deploy a dynamic panel analysis to quantify the total factor productivity impact associated with export-market transitions amongst British firms between 1996 and 2004. Real gross output is modelled as a function of employment, intermediate inputs, tangible assets, and export-market transition dummies with various lags. To reiterate, they found that new exporters enjoyed a 22% increase in TFP during the year of entry, while firms exiting overseas markets experienced a 15% decline in TFP. In keeping with findings from Harris and Moffat, manufacturing firms suffered the most after exiting overseas markets.

More dated econometric research is in keeping with the established findings in that it supports the notion that involvement in trade has a positive effect on UK productivity. Rizov and Walsh (2009) demonstrated that increased exposure to international trade was significant in explaining improvements in aggregate productivity in UK manufacturing between 1994 and 2001. Meanwhile, Crespi et al. (2008) found that newly exporting UK firms were

25% more productive than non-exporting peers in the two years after exporting, and that past exporting was positively associated with learning from buyers. Lastly, Greenway et al. (2007) found convincing evidence that participation in export markets improves firms' financial health.

Qualitative research also supports the notion that involvement in trade has a positive effect on UK productivity. For example, Kneller and Pisu (2010) draw on survey data from a UKTI (UK Trade and Investment) funded project from 2005. Of the firms surveyed, 63.5% reported increased profits as a result of exporting, while 47.4% reported increased efficiency (the closest to a direct measure of productivity among the survey questions) as a result of exporting.

Interestingly, none of the reviewed studies highlight regional distinctions in the impact of changes in trade on productivity. This represents a fruitful avenue for further research.

3.3.3 The consequent impact of trade-related productivity changes on the UK economy

The second half of this section focuses on literature relating to the consequent impact of trade-related productivity changes on the UK economy.

In terms of its overall impact on the economy, trade can have both a positive and negative impact on UK employment. A rich body of literature looks at the *overall* impact of trade on UK jobs and wages. For instance, The Fraser of Allander Institute (2021) provides a thorough analysis of the impact of exports on UK employment and earnings. Utilising input-output tables, the authors estimate that 13% of UK jobs were directly supported by exports in 2016, rising to 23% and 39% once indirect and induced effects are accounted for. They also estimate that jobs directly and indirectly supported by exports have higher wages than the national median.

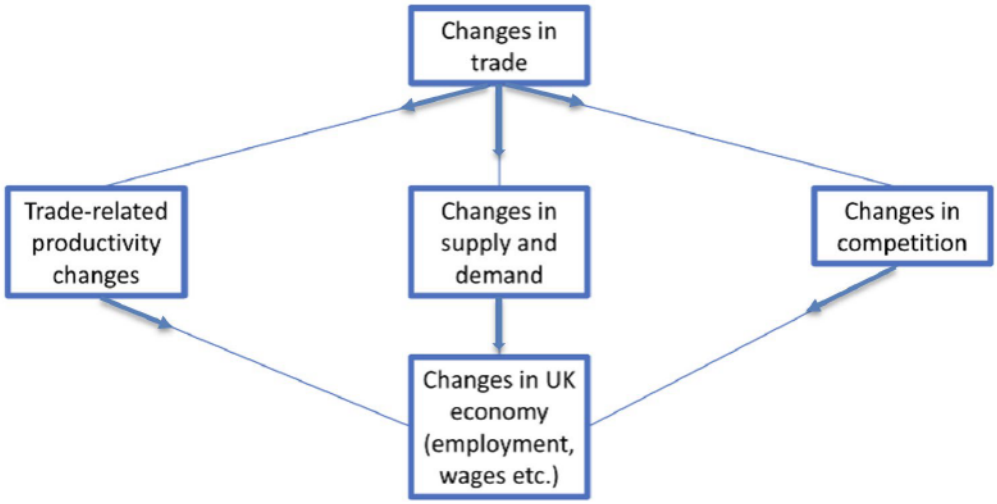
Other research has focused on import competition. De Lyon & Pessoa (2021) find that workers initially employed in sectors highly exposed to growth in imports from China (as measured by the change in Chinese imports between 2000 and 2007 divided by expenditure in a sector in the UK) experienced 3.11% lower income growth than those initially employed in less-exposed sectors.

Finally, “offshoring” and the role of intermediate imports have attracted significant attention. Magli (2022) identifies a positive aggregate employment and average wages elasticity to services offshoring by UK firms. Specifically, a 10% increase in broad offshoring exposure of a sector-local area corresponds to a 1.3% rise in employment and a rise in average wages of 0.5%. Gagliardi et al. (2015) found that offshoring by UK firms has generated significant job losses in routine occupations but had a positive effect on the generation of nonroutine jobs.

No researchers have attempted to isolate and measure the effects of trade-induced productivity changes on the wider economy. Disentangling the effects of trade-induced productivity changes from other trade effects, such as

heightened demand and import competition, is theoretically challenging. As far as this study found, this has not been attempted.

Figure 7: Simplistic representation of the difficulties of isolating trade-induced productivity changes from other trade effects



In the absence of research on this, the review now turns to the literature documenting the impact of productivity changes on employment and wages. Subsequently, it may be possible to make some rough inferences on the economy-wide effects of the trade-induced productivity changes identified above.

As with international trade, research suggests that the impact of productivity on employment is multifaceted, but likely to be net positive. Technical innovation and efficiency gains may displace jobs but do not necessarily reduce aggregate labour demand. This is because productivity gains simultaneously induce countervailing responses that include output and final demand effects (Autor and Salomons, 2018).

This is broadly evident in a sectoral analysis of the UK economy over the past three decades (Swinney, 2018). From 1990-2017, the 'exporting' sectors in finance and manufacturing enjoyed labour productivity growth of 80% and 95%, respectively. Yet, the number of jobs in these sectors fell by up to 45%. Meanwhile, local services sectors like accommodation and food, services and arts, recreation, and entertainment saw productivity growth of less than 20%, but accounted for a large proportion of job creation during this period with employment growth in excess of 30%.

There are some notable exceptions to this seemingly inverse relationship. The information and communications sector has managed to provide both productivity and employment growth. Moreover, Swinney concludes that increasingly efficient sectors have spurred employment in other areas. For example, wage increases in highly productive exporting sectors have increased

the demand for local services. This is supported by more dated econometric research which demonstrates that TFP growth increased aggregate employment in the United States, Japan, and the EU (Pissarides & Vallanti, 2004).

Meanwhile the impact of productivity growth on employee compensation is positive. Although there is some dispute over the impact of productivity growth on wages in the UK, reviewed research demonstrates that employee mean hourly compensation grew at the same rate as labour productivity between 1981 and 2019 (Teichgräber & Van Reenen, 2021; Pessoa & Van Reenen, 2012). There has been some "decoupling" between productivity and median real wages. This can be attributed to rising inequality and non-wage labour costs.

3.3.4 Application to the UK policy context

All the research cited above is UK-specific. With regards to the policy context, the cited research does confirm some of the key lessons highlighted in Research Questions 1 and 2.

First, productive UK firms are more likely to engage in international trade, to begin with (ESCoE, 2018; Crespi et al., 2008 etc.). This is in keeping with established theory (Melitz, 2003), and the "selection channel" identified in section 3.1. **This implies that productive UK firms may be more receptive to trade promotion activities undertaken by DBT and other organisations.**

Second, studies controlling for endogeneity provide good evidence for the impact of changes in trade on UK productivity (Son, 2021; Harris & Moffat, 2015; Harris & Li, 2012 etc.). This occurs through market share reallocation, but also within-company productivity growth (learning-by-exporting, innovation, access to imported intermediaries etc.), with non-trading firms also benefiting via spillovers (Rizov and Walsh, 2009; Crespi et al., 2008).

Best estimates suggest that engaging in international trade is associated with a *subsequent* increase in firm-level TFP ranging from 3%-22%. As a best central estimate derived from the most recent causal analysis, engaging in importing and exporting is associated with a subsequent increase in TFP of 6.7% amongst UK firms. Productivity gains seem most pronounced in UK firms that import, and export as opposed to UK firms that engage in just one of these activities (Harris & Moffat, 2015; Harris & Li, 2012; Crespi et al.). **This implies that successful trade promotion can foster productivity improvements amongst UK firms.**

Third, the impact of changes in trade on UK productivity vary by sector. For the most part, Trade-related productivity gains appear more pronounced in UK manufacturing firms than in other UK firms (Harris & Moffat, 2015). **This highlights the importance of targeting trade promotion activities for the purpose of domestic productivity growth.**

Fourth, there is evidence that exiting international markets can be detrimental to UK productivity (Harris and Li, 2012). This underscores the

importance of sustained international trade in fostering domestic productivity gains.

Fifth, heightened TFP has sometimes led to the displacement of jobs in sectors enjoying productivity gains (Swinney, 2018). Regardless, improved efficiency has likely fostered an aggregate rise in labour demand through a range of induced effects. These include an increase in employee mean compensation that is broadly equal to any productivity growth (Teichgräber & Van Reenen, 2021; Pessoa & Van Reenen, 2012). This implies that trade promotion activities and subsequent productivity gains are likely to exhibit a net-positive effect on UK employment and wages.

3.3.5 Challenges with applications to the UK policy context

Whilst this research draws on data from the UK, there are some challenges with applications to the UK policy context.

Data issues have limited our ability to make simple inferences like "if trade goes up or down by x% then productivity increases/decreases by y%." Evidence in the UK has been hampered by long-standing data issues, particularly the lack of business-level data which contains information about both financial performance and trading behaviour (ESCoE, 2018). Much of the existing research relies on dummy variables for trade participation which are less representative of trade intensity than trade flows themselves. Dummy variables for trade participation also prevent us from making simple inferences like "if trade goes up or down by x% then productivity increases/decreases by y%."

Data on productivity is more abundant because of the Annual Business Survey (ABS), which collects information on employment, capital expenditure, intermediate inputs, and other variables of interest. But the ABS is limited by its sample size, relative to other inquiries (Harris & Moffat, 2015).

Furthermore, the existing research fails to distinguish between UK regions and nations. This limits the extent to which policymakers can be sure that the key lessons outlined above apply consistently to all UK nations and regions.

Lastly, there is a larger research gap on the consequent impact of trade-related productivity changes on the UK economy. Rather than the absence of data, this can be attributed to the methodological challenges of isolating trade-related productivity changes from other trade effects. Some rough inferences can be made based on the effects of productivity changes more broadly, but these should be treated with caution. Trade-related productivity changes probably exhibit certain tendencies. For instance, they are likely concentrated in specific industries or sectors.

3.3.6 Addressing challenges and overall conclusions

Data availability has improved over the past five years, such that it would now be possible to make simple inferences like "if trade goes up or down by x% then productivity increases/decreases by y%". With regards to

quantifying the impact of changes in trade on productivity in the UK, the data issues outlined above have already been solved to some extent. The Linked Trade-in-Goods/Inter-Departmental Business Register dataset contains firm-level information on goods trade flows and labour productivity. Attempts have also been made to link the Annual Business Survey (ABS) with trade in goods data. This would allow for an enquiry into the effects of goods trade flows on total factor productivity. Finally, the International Trade in Services dataset contains firm-level data on services trade (in certain sectors) which could be linked to either the IDBR or the ABS.

Each of these solutions is accompanied by certain caveats that will be discussed in more detail in the following section. Nonetheless, *existing* datasets can now facilitate a firm-level investigation of the impact of changes in trade *flows* on productivity amongst UK firms. This would allow researchers to draw conclusions like "on average if trade goes up or down by x% then productivity increases/decreases by y%".

There is also no reason why researchers would not be able to distinguish between UK regions and nations at the level of International Territorial Level 1 (ITL 1), as each of the above datasets contains information on firm location.

Filling the research gap on the consequent impact of trade-related productivity changes on UK employment and wages is more complex. Disentangling the effects of trade-induced productivity changes from other trade effects, such as heightened demand and import competition, is theoretically complex. As far as this study has found, no existing methodology broaches this challenge.

Looking ahead, a mediation analysis could be deployed similar to the one used by Dhingra et al. (2016) to assess the effects of Brexit (and reduced trade) on living standards. The elasticity of productivity with respect to trade could be combined with the elasticity of employment / wages with respect to productivity to produce an estimate for the effects of trade-related productivity changes on employment / wages.

Overall, existing UK-specific research underscores the importance of international trade as a lever for improving and sustaining productivity and employment growth amongst UK firms.

3.4 Approaches to measuring the impact of trade on productivity

3.4.1 Headline description

This section covers both the approaches used to estimate firm-level productivity, and the methods used to estimate the impact of trade on productivity.

This review identifies several standard approaches to measuring the impact of trade on UK productivity. More specifically, it provides an overview of the data requirement, and the advantages and disadvantages of methods used to estimate the three main measures of firm-level productivity: labour

productivity, total factor productivity, and indirect measures of productivity such as innovation and management quality.

The report recommends conducting research on the impact of trade on productivity using matched firm-trade data for the UK.[47] More specifically, it recommends estimating productivity using alternative measures and methods, including the most rigorous control function methods, to ensure the effects are not driven by the choice of the productivity measure. Empirical analyses should consider different dimensions of trade, such as importing and exporting, but also differences in export and import scope (e.g., variations in number and type of products/inputs and destinations/origins), and differences between industries and sector characteristics (e.g., market concentration or technological level).

The report also recommends improving data collection and matching across sources to improve firms and variables coverage. While the available matched firm-trade data offer the opportunity to conduct useful research on the link between trade and productivity, they still have some limitations in terms of sample coverage.[48] The ultimate aim should be to compile a comprehensive dataset that tracks a large and representative sample of firms, in terms of size, sector and location, over time. Matching firms to trade data also offers the opportunity to incorporate additional variables of interest from other ONS sources. This is because once the existing trade data has been matched to either the ABS or the IDBR, it is straightforward to also match it with other ONS firm-level datasets. In particular, the Business Expenditure on R&D (BERD) survey could be used to obtain measures of firm-level R&D investment, the Community Innovation Survey (CIS) could be used to provide other direct measures of innovation, such as product and process innovation, and the International trade in services data (ITIS) could be used to link trade in goods with trade in services at the firm level.

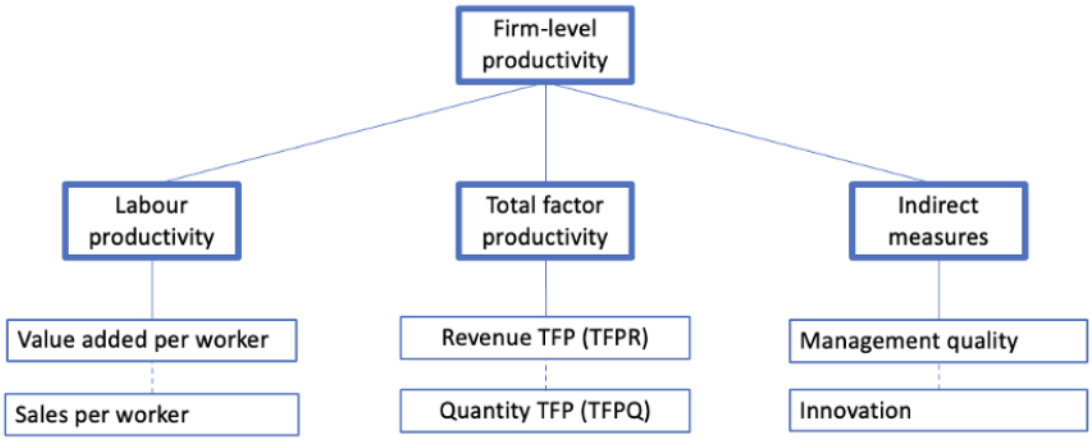
3.4.2 How to measure productivity

The literature review has identified three main measures of firm-level productivity: labour productivity, total factor productivity (TFP), and indirect measures of productivity (***Figure 8***).

[47] *There are two firm-trade matched datasets available. The first dataset refers to matched firm and custom data for the period 2005-2016 (ABS-HMRC). The second dataset refers to matched administrative and custom data also for the period 2005 to 2016 (IDBR-HMRC).*

[48] *At the moment the ABS dataset, which contains all the variables necessary to compute total factor productivity, covers a small sample of firms and the set of small and medium-sized firms covered changes from one year to the next. Consequently, time series data required to study changes in firm-level productivity are only available in the ABS for relatively large firms.*

Figure 8: Different measures of productivity



In this subsection, the advantages and disadvantages of each method are summarised below (***Table 1*: Summary of TFP measures**), while additional details are provided in the technical appendix.

Table 1: Summary of TFP measures

Measure	Approach	Data requirements	Pros	Cons
Labour productivity	Labour productivity is commonly measured by the logarithm of deflated value added per worker or sales per worker.	Value added or sales, and the number of employees.	It is the simplest measure of productivity as it does not require estimating a production function and has minimum data requirements compared to other measures. It can be used with cross-sectional data.	While this measure does not require assumptions, it has the drawback that observed productivity increases could be driven by capital accumulation rather than efficiency gains or technological change.
Total factor productivity (TFP)	There are several approaches to estimating TFP, which are described in the technical appendix. Approaches differ in terms of the level of rigour and data requirements.	All measures of TFP require data on deflated sales (or value added), assets, and employment. Besides this minimum data requirement, different methods can require some additional variables, such as investment, material expenditure or information on firm-level products. Most methods require panel data, preferably long.	This category of measures considers all factors of production (labour and capital) and are better suited to capture technological progress. There is a variety of methods to estimate TFP, which can suit different data and research needs.	This category of measures is more demanding in terms of data and can get computationally complex, especially for more rigorous methods. Unless corrected for, standard measures of TFP (known as TFPR) conflate productivity effects with price effects (markups). Pure productivity (TFPQ) can be estimated but require more complex methods and additional data requirements.

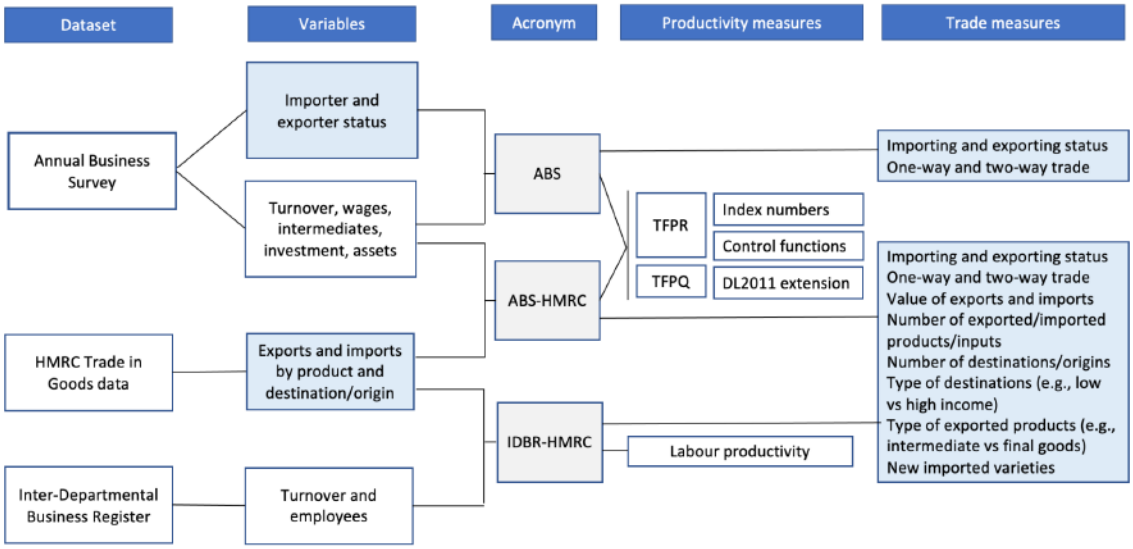
Indirect measures of productivity	Measures include management quality and innovation (R&D expenditure or patents)	Management quality is measured by conducting tailored surveys. Innovation can be measured by R&D expenditure, which is sometimes recorded in standard firm-level surveys. Patents instead are obtained from Patents registers. and need to be matched to firm-level data.	One of the advantages is that these measures can be considered a concrete, tangible and direct measure of TFPQ, i.e., pure productivity net of any markups, and so can circumvent some estimation concerns. In addition, they also allow for delivering some clear policy recommendations.	These measures are quite demanding in terms of data requirements as they either require costly data collection through tailored surveys or, in the case of patents, data need to be retrieved and matched to firm-level data, and this is only possible if firm identifiers are made available. It is also noted that innovation expenditure or patents do not always lead to improvements in productivity.

Note: TFPQ stands for Quantity-based productivity, obtained by using firm-level prices to deflate revenues, while TFPR stands for Revenue-based productivity, obtained by using sector-level price indexes to deflate revenues. TFPQ is considered a good proxy for technical efficiency, as it is a closer approximation to how much output can be obtained from given inputs. TFQR instead captures both technical efficiency and markups. This is because the output is proxied by revenues and conflates both quantity and price changes.

3.4.3 Application to the UK policy context

It is essential to conduct empirical research using up-to-date data to analyse the effect of trade on the productivity of UK firms. Such evidence-based analysis can inform policy decisions and help address the productivity challenges faced by the UK. This section provides suggestions regarding the methods that can be applied to UK data to estimate the impact of trade on productivity. Figure 9 summarises the three available datasets and the measures of productivity and trade that can be applied to them. The remaining of the section focuses on two key datasets. The first dataset refers to matched firm and custom data for the period 2005-2016 (ABS-HMRC). The second dataset refers to matched administrative and custom data also for the period 2005 to 2016 (IDBR-HMRC). The two datasets are different in terms of firm coverage, and the variable available to measure productivity, while both datasets contain the same trade-related variables. This section also presents possible sector classifications that can help investigate the heterogeneity of the responses across sectors.

Figure 9: Summary of available datasets and recommended measures



Note: TFPQ stands for Quantity-based productivity, obtained by using firm-level prices to deflate revenues, while TFPR stands for Revenue-based productivity, obtained by using sector-level price indexes to deflate revenues. DL2011 stands for De Loecker (2011).

While the available data offer the opportunity to conduct useful research on the link between trade and productivity, they still have some limitations. While the IDBR data cover the universe of firms, the ABS dataset covers a much smaller sample and the set of small and medium-sized firms covered by the ABS changes from one year to the next. Consequently, time series data required to study changes in firm-level productivity are only available in the ABS for relatively large firms. At the same time, the weights available in the ABS can be used to construct industry-level measures of output, employment, productivity, etc. for sector-level analyses.

3.4.4 Estimating productivity

Matched firm-trade data (ABS-HMRC)

This dataset combines the following sources: HMRC Trade in Goods data (transaction level) and Annual Business Survey (ABS). It includes the following firm-level variables: turnover, wages and salaries, purchases of goods and services, stocks and capital expenditure, and regional and sector classifications.[49]

Based on data availability, productivity can be computed using the following methods, ordered in terms of complexity:

1. Index number: this method is straightforward and avoids losing observations as it does not use lagged variables. It is recommended to estimate weights separately for each 2-digit sector. Given the

[49] *It is assumed that, although data have been extracted by deciles, they will be available at individual level for the purpose of the analysis.*

unavailability of firm-level prices, values should be deflated using sector-level deflators.

2. Control function methods: It is recommended to begin with OP/LP methods and the extension proposed in De Loecker (2007, 2013) to augment the production function with importing or/and exporting status.[50] LP should be preferred if the investment variable is reliable, and firms do not report zero investment. It is also recommended to use of the ACF method for robustness checks and estimating TFP separately for each 2-digit sector.[51] Given the unavailability of firm-level prices, values should be deflated using sector-level deflators. Note that these methods will not allow separating pure productivity effects from price effects.
3. DL2011 method: given the availability of firm-level product categories, the production function can be augmented following the approach in De Loecker (2011) to separate productivity effects from price effects and get a better approximation of technical efficiency (TFPQ).

Papers that have used similar data to look at the impact of trade on productivity include Bas and Strauss-Kahn (2014) for France, Chen and Steinwender (2021) for Spain, and Damijan et al. (2014) for Slovenia.

Matched administrative-trade data (IDBR-HMRC)

The dataset combines the following sources: HMRC Trade in Goods data (transaction level) and the Inter-Departmental Business Register (IDBR). It includes the following firm-level variables: turnover and employees, regional and sector classification.[52] The only possible measure of productivity for this dataset is labour productivity, constructed as the logarithm of deflated turnover over employees. Given the unavailability of firm-level prices, turnover should be deflated using sector-level deflators.

Papers that have used similar data to look at the impact of trade on productivity include Mayer et al. (2021) and Corcos (2013) for France and Koch (2021) and Chen and Steinwender (2021) for Spain.

3.4.5 Estimating the impact of trade on productivity

The following trade variables are available in both datasets: Export and import values by product (HS 6 digit) and destination/origin. Based on these variables, several indicators can be constructed to capture different aspects of trade:

- Export participation (binary variable) to investigate selection into exporting and the impact of exporting on productivity. Examples include De Loecker, J. (2007), Crespi et al. (2008) and Koch et al. (2021).

[50] *OP stands for Ollie and Pakes (1996) and LP stands for Levinsohn and Petrin (2003), see the Technical Appendix for more details.*
[51] *ACF refers to Ackerberg et al. (2015), see the Technical Appendix for more details.*
[52] *It is assumed that, although data have been extracted by deciles, it will be available at individual level for the purpose of the analysis.*

- Distinguish exporting to high and low-income countries to detect learning from exporting. See for example De Loecker (2007.)
- Distinguish between different initial levels of productivity to detect catching-up effects. See for example Lileeva and Trefler (2010).
- Degree of internationalisation to explore the difference between firms that do not engage in international trade, firms that engage in one-way trade (either importing or exporting) and firms that engage in two-way trade (exporting and importing). This allows for investigating complementarities in entry costs between importing and exporting, and the direct and indirect effects of importing on exporting. See for example Turco and Maggioni (2013), Harris et al. (2015), Haller (2012), and Aristei et al. (2013).
- The number of exported products to investigate product innovation. See for example Bloom et al. (2021)
- Distinguish between the type of exported products, e.g., intermediates or final goods, to explore how trade effects depend on the position along the global value change. See for example Benkovskis et al. (2020).
- The number of imported inputs to investigate the role of increased input varieties, and input complementarities. See for example Bas and Strauss-Kahn (2014), and Halpern et al. (2015).
- The Share of new foreign varieties in the total number of imported input varieties to investigate how firms experiment with new intermediate inputs and their effect on productivity. See for example Colantone and Crinò (2014).
- The value of exports and imports to investigate how increasing the scale of operation can impact productivity. See for example Lileeva and Trefler (2010).
- Separate Imports from high and low-income countries to investigate the cost-saving mechanism through which importing affect productivity. See for example Turco and Maggioni (2013).

Note that the evidence obtained by using the measures of trade discussed above is likely to produce descriptive results, i.e., associations, rather than causal estimates unless appropriate empirical methods are used to address potential confounding factors. Methods vary notably and are specific to the chosen indicator and are thus not described here. However, most of the papers mentioned in the examples provide some useful suggestions on how to address some of the empirical concerns. It is also worth noting that several papers reviewed in this report also remain descriptive. While descriptive studies do not necessarily establish causal relationships between the variables of interest, they can still be informative and useful in providing important insights into the patterns observed in the data and stimulate future research into establishing potential causal mechanisms. One notable example in this regard is the study by Muuls

and Pisu (2009) that highlights a comprehensive set of empirical analyses, some descriptive and others more advanced, that can be employed to explore matched firm-trade data considering both importing and exporting activities.

Sector-level impacts

The impact of trade on productivity has been found to vary by sectors. Yet, there is no unifying theory to explain these discrepancies, highlighting the need for UK-specific empirical analyses to better understand the relationship between trade and productivity in different sectors. The literature on the differences in the impact of trade on productivity across sectors is limited. Mayer et al. (2021), for example, show disaggregated effects of export demand shocks on productivity for French manufacturing sectors. The study shows that there is variation in productivity gains but does not investigate further the mechanisms behind such differences. Schwarzer (2017) considered data for German firms for the period 1993-2014. The study also provided disaggregated effects by sector in both manufacturing and services and found that learning-by-exporting effects are not present in all sectors and, in general, are weaker in the service sector. The study goes a step further and provides suggestive evidence showing that productivity gains from exporting are larger in sectors that are relatively more concentrated, i.e., less competitive. Harris and Moffat (2015) using data for the UK in 2011-2012, found that manufacturing firms that both import and export enjoy productivity gains from trade regardless of whether they trade goods or services. For services firms (excluding wholesale and retail) instead, the results are mixed. Finally, for wholesale and retail firms, they found that exporting and/or importing goods is both a very frequent and a productivity enhancing activity. Breinlich and Criscuolo (2011), also considering the UK, distinguished between high-tech and low-medium tech sectors. They show that participation in trade in services vary across the two groups, but do not investigate whether productivity effects might also vary.

To explore sector-level differences in trade-related productivity gains for the UK the following disaggregation and classifications can be used:

- Manufacturing vs Service sector vs Wholesale and retail as in Breinlich and Criscuolo (2011) and Harris and Moffat (2015) for the UK.
- 2-digit industrial classification, as in Mayer et al. (2021).
- High tech and low-medium tech sectors, as in Breinlich and Criscuolo (2011).[53]
    - There is also a more detailed four-group categorisation: high, medium-high, medium-low, and low based on Hatzichronoglou, 1997.[54]
- Level of market competition as in Schwarzer (2017), obtained by constructing a Herfindahl index at sector level. The Herfindahl index is determined by summing up the square of the market shares of each firm.

[53] *The study provides a table in the Appendix indicating how sectors have been categorised into high-tech and low-tech.*
[54] *The sectors belonging to each category are listed here: https://www.oecd.org/sti/ind/48350231.pdf*

The resulting index is an indicator of how concentrated, or competitive, a market is within an industry. The higher the index, the higher is market concentration.

- As net-zero policies and targets are becoming more prominent, it is worth exploring differences across sectors according to their level of energy intensity. The energy intensity of the UK sectors is provided by the ONS.[55]

3.4.6 Challenges with applications to the UK policy context

Good data availability is crucial to conduct empirical analysis of the relationship between trade and productivity. Recent studies have demonstrated the value of combining firm-level data, covering the essential variables for the construction of TFP (revenues, employees, and assets) or innovation (patents) with customs-level data (imports or exports at product and destination level). This is the case, for example, for studies on France (Bas and Strauss-Kahn, 2014; Mayer et al., 2021; Corcos, 2013; and Aghion, 2022), Spain (Koch, 2021; Chen and Steinwender, 2021) and Slovenia (Damijan et al. 2014). While matched firm and custom data has become available for the UK for the period 2005-2016, the coverage is still limited. An alternative matched administrative and trade dataset has also become available for the period 2005 to 2016 (IDBR-HMRC). This latter dataset, however, does not cover all the essential variables required for calculating TFP. Therefore, only basic measures of productivity such as labour productivity can be computed.

3.4.7 Addressing challenges and overall conclusions

To address the limitations of existing evidence, this report recommends conducting research on the impact of trade on productivity using available matched firm-trade data.[56] This will allow obtaining up-to-date evidence that reflects current economic conditions, technological advancements, and the evolution of global supply chains. When possible, it is recommended to estimate different measures of productivity to ensure the estimated effects are not driven solely by the choice of one particular productivity measure. It is also recommended to investigate the impact of different dimensions of trade, such as importing and exporting, but also differences in export and import scope (e.g., variations in number and type of products/inputs and destinations/origins). Finally, to better understand how firms in different sectors might respond differently to trade shocks and opportunities, it is recommended to disaggregate the effects at the sector level, but also to consider different sector classifications to identify possible underlying mechanisms.

To address the limitations faced in estimating the relationship between trade and productivity for the UK, improving data collection and matching across sources should be a key priority. The ultimate aim should be to compile a comprehensive dataset that covers all the relevant variables for the

[55] *https://www.ons.gov.uk/economy/environmentalaccounts/datasets/ukenvironmentalaccountsenergyreallocatedenergyconsumptionandenergyintensityunitedkingdom*

[56] *See Section 3.4.4 for details on the two available matched firm-trade data sources, the ABS-HMRC data and the IDBR-HMRC data.*

construction of TFP using the most sophisticated methodologies and detailed customs-level data. Hence, efforts should be directed towards establishing sound foundations for data collection and management to support empirical analyses to inform policy decisions and help address the productivity challenges faced by the UK. In addition, data should be made available to the wider academic community, not only to promote transparency and reproducibility but also to spur research collaborations and enable more in-depth and rigorous analyses that might not be feasible within the timeframes of policy institutions.

Matching firms to trade data offers the opportunity to incorporate additional variables of interest. Once trade data have been matched to either the ABS or the IDBR, it is straightforward to also match it with other ONS firm-level datasets. In particular, the Business Expenditure on R&D (BERD) survey could be used to obtain measures of firm-level R&D investment and the Community Innovation Survey (CIS) could be used to provide other direct measures of innovation. This matching can be done using the ONS Secure Research Service (SRS), since the Linked Trade in Goods-IDBR dataset is available in the SRS. This would also enable the linking of trade in goods with trade in services (ITIS) data at the firm level.

4 Conclusions

This review has yielded several insights on the links between firm-level productivity and exporting and importing. This concluding section pulls together the main insights and highlights the resulting implications for UK policy.

First, the review has found that the link between exporting and productivity is a two-way process. On the one hand, firms that are better managed and invest in innovation are more likely to export, partly due to the presence of entry costs in the export market. On the other hand, exporting itself also leads to higher productivity. This productivity premium is reserved for exporters who can reach more countries where firms can learn from their international competitors, serve larger markets, and enjoy higher returns on their investments, thus being incentivised to invest in innovation. This leads to an increase in export demand, which further stimulates innovation and productivity.

The fact that more productive firms are more likely to export suggests that a key lever for government policy to increase exports is to pursue policies that increase the productivity of UK firms, in particular SMEs, to enable them to go onto the next step of their business expansion by starting to trade overseas. Such policy should be implemented in parallel to existing proportional export support and promotion to ensure sustained export success and hence productivity improvements for UK firms, especially SMEs. Given the range of factors that contribute to productivity, this calls for a combined effort across government to ensure complementary policies that support trade are leveraged. Considering that any such productivity improvements will require investment from UK firms, and that investment requires certainty, a key supporting role DBT can play in this context is to ensure long-run stability in the trading environment faced by UK firms, for example by locking in long-term access to key markets through FTAs and by championing free trade and the rules-based multilateral system.

This review has also highlighted an important link between importing and productivity. This is because importing enables businesses to access inputs that are not available domestically (possibly at a lower price), to experiment with new combinations of inputs to optimise production processes and to create new products.

Furthermore, firms that manage to engage in both importing and exporting (two-way trade) tend to have a larger productivity advantage, consistent with higher entry costs to two-way trade. Studies show that firms engaged in importing are more likely to enter export markets due to the common investments they have already made in acquiring the necessary resources and capabilities for international trade. There is also evidence that jointly exporting and importing confers additional productivity gains to firms, after entry, compared to engaging in one of the two activities only.

This has several important implications for UK policymakers. First, FTAs should continue to focus on lowering tariffs and removing further barriers to entry in markets. Lower tariffs on UK imports will stimulate the importing activities of UK

firms, while lower tariffs in foreign markets will stimulate entry into these markets and hence UK exports. In this sense, FTAs can be leveraged to harness the productivity-enhancing effects of both importing and exporting.

Second, given that a large part of UK imports takes place along complex supply chains, taking advantage of the productivity-enhancing effects of imports will require strengthening the resilience of the supply chains in which UK firms are involved. Policymakers can help this process by refraining from imposing tariffs on intermediate inputs, for example in the form of anti-dumping duties, and instead try to lower such tariffs through the continued implementation of FTAs.[57] In addition, there is also a role for putting robust systems in place that allow firms to handle unexpected financial or supply chain shocks caused by natural disasters such as the Covid pandemic. In this context, this review has highlighted the importance of firms holding a sufficient number of inventories to allow the weathering of such unexpected shocks.

Regarding the UK context specifically, this review has confirmed a firm-level link between international trade participation and productivity. As in the wider literature, productive UK firms are more likely to trade to begin with, which suggests that productive UK firms may be more receptive to trade promotion activities undertaken by DBT and other organisations. Furthermore, and consistent with the wider literature, UK businesses enjoy further productivity gains after engaging in international markets.

Evidence suggest that engaging in international trade is associated with a subsequent increase in firm-level productivity ranging from 3%-22%. As a best central estimate derived from the most recent causal analysis, engaging in importing and exporting is associated with a subsequent increase in TFP of 6.7% amongst UK firms. Unlike the 20-40% range referred to above, these figures are derived from studies that account for self-selection. In other words, this is an estimate for productivity gains amongst UK firms that occur *because of* engaging in international trade. Productivity gains seem most pronounced in UK firms that import and export as opposed to UK firms that engage in just one of these activities. This implies that successful and comprehensive trade promotion, which focuses on imports as well as exports, is most effective in fostering productivity improvements amongst UK businesses.

This review has also highlighted evidence of diminishing productivity after firms exit international markets. In tandem with the wider literature on supply chain shocks, these findings support the notion that disruptions to trade will have a negative effect on UK productivity. This only underscores the importance of guarantees provided through comprehensive FTAs and the rules-based multilateral system.

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[57] *Note that while the existing empirical evidence strongly supports the conclusion that reducing intermediate input tariffs increases firm-level productivity, there is currently a lack of UK-specific evidence on this topic, so the recommendation to lower intermediate input tariffs is subject to the caveat that existing evidence is not UK specific (see Section 3.2.5 for further details)*

With that said, the UK-specific literature is limited by its focus on international trade participation in the absence of data on firm-level trade flows. Currently available data also have significant shortcomings in terms of coverage[58], preventing the computation of productivity measures for large parts of the population of UK firms. There is also an absence of research that distinguishes between UK nations and regions, which represents another avenue for further research.

Besides reviewing the wider literature on the links between firm-level productivity and exporting and importing, this review has also provided a comprehensive summary of the different productivity measures used in the literature and their application in a UK context.

The report recommends conducting research on the impact of trade on productivity using matched firm-trade data for the UK. There are two firm-trade matched datasets available. The first dataset refers to matched firm and custom data for the period 2005-2016 (ABS-HMRC). The second dataset refers to matched administrative and custom data also for the period 2005 to 2016 (IDBR-HMRC).[59] More specifically, it recommends estimating productivity using different measures and methods[60], including the most rigorous control function methods, to ensure that the estimated effects of trade participation on productivity are not driven by the choice of the productivity measure. Empirical analyses should also consider different dimensions of trade, such as importing and exporting, but also differences in export and import scope (e.g., variations in the number and type of products/inputs and destinations/origins), and differences between industries and sectors (e.g., in terms of market concentration or technology level).

The report also recommends improving UK data collection and matching across sources to improve firms and variable coverage. While the available matched firm-trade data offer the opportunity to conduct useful research on the link between trade and productivity, they still have some limitations in terms of firm coverage. At the moment the ABS dataset, which contains all the variables necessary to compute total factor productivity, covers only a small sample of firms and the set of small and medium-sized firms covered changes from one year to the next. Consequently, time series data required to study changes in firm-level productivity are only available in the ABS for relatively large firms.

The aim should be to compile a comprehensive dataset that tracks a large and representative sample of firms (in terms of size, sector, and location) over time and also contains information about the trading activities of firms, including both export and import status, as well as the value of imports and exports. Matching

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[58] *At the moment the ABS dataset, which contains all the variables necessary to compute total factor productivity, covers a small sample of firms and the set of small and medium-sized firms covered changes from one year to the next. Consequently, time series data required to study changes in firm-level productivity are only available in the ABS for relatively large firms.*

[59] *See Section 3.4.4 for more details on these datasets.*

[60] *The most commonly used productivity measures are labour productivity, total factor productivity and indirect indicators of productivity such as innovation measures (e.g., counts of patents). The best methods currently available are the approaches by Olley and Pakes (1996), Levinsohn and Petrin (2003) and Ackerberg et al. (2015). Please see Section 3.4 for details on these methods.*

firms to trade data also offers the opportunity to incorporate additional variables of interest from other ONS sources. This is because once the existing trade data has been matched to either the ABS or the IDBR, it is straightforward to also match it with other ONS firm-level datasets. In particular, the Business Expenditure on R&D (BERD) survey could be used to obtain measures of firm-level R&D investment, the Community Innovation Survey (CIS) could be used to provide other direct measures of innovation, such as product and process innovation, and the International trade in services data (ITIS) could be used to link trade in goods with trade in services at the firm level.

5 Technical Appendix

The first part of this technical appendix provides details on the academic papers reviewed in this study, including summaries, a brief discussion of limitations and the reason why they were selected for the review. The second part of this appendix provides an overview of the different measures of productivity used in the literature and of the approaches to estimating the impact of trade on productivity.

5.1 Studies included in this review

The tables below contain the complete set of academic papers reviewed as part of this study, including bibliographical details, a brief discussion of limitations and the reason why they were selected for the review.

Table 2: Studies on the relationship between exporting, importing and productivity (part I)

Title	Country	Period	Productivity measure	Trade measure	Method	Reason for inclusion
De Loecker, J. (2007). Do exports generate higher productivity? Evidence from Slovenia. *Journal of international economics*, 73(1), 69-98.	Slovenia	1994-2000	TFPR estimated using OP by sector (2 digit). Investment depends on export status.	Export participation (entry). Difference between high- and low-income regions	Incorporating export status into OP method (decision to invest and exit). Matching on observables	Consider learning from high income regions.
Greenaway, D., Guariglia, A., & Kneller, R. (2007). Financial factors and exporting decisions. Journal of international economics, 73(2), 377-395.	UK	1993-2003	TFP (LP)	Liquidity, leverage, exporting	Linear probability model. Probability of exporting	Considers selection into exporting.
Crespi, G., Criscuolo, C., & Haskel, J. (2008). Productivity, exporting, and the learning-by-exporting hypothesis: direct evidence from UK firms. Canadian Journal of Economics, 41(2), 619-638.	UK	1994-1996-1998-2000	Labour productivity (sales per workers)	Export status	Linear regression, cross section and firm fixed effects, with lagged explanatory variables. With some falsification tests.	Consider Learning-by-exporting through customers. Also looks at selection.
Lileeva, A., & Trefler, D. (2010). Improved access to foreign markets raises plant-level productivity… for some plants. The Quarterly journal of economics, 125(3), 1051-1099.	Canada	1984, 1996	LP (Value added per worker)	Exporting status and volume of exports (Explanatory variable = ln(export) for exporters and zero for non-exporters). But also importing intermediates.	Instrument exports using US tariff cuts	Consider learning by exporting (largest for least productive firms - catching up)
Breinlich, H., & Criscuolo, C. (2011). International trade in services: A portrait of importers and exporters. Journal of International Economics, 84(2), 188-206.	UK	2000-2005	LP (gross value added per employee), TFP residual of value-added production functions	Importing and exporting		Consider selection into exporting. Separately for manufacturing and services with focus on trade in services.

Notes: OP stands for Olley and Pakes (1996); TFP(LP) stands for total factor productivity estimated using the Levinsohn and Petrin (2003) method; LP stands for labour productivity.

Table 3: Studies on the relationship between exporting, importing and productivity (part II)

Title	Country	Period	Productivity measure	Trade measure	Method	Reason for inclusion
Haller, S. A. (2012). Intra-firm trade, exporting, importing, and firm performance. Cana dian Journal of Economics/Revue canadienne d'économique, 45(4), 1397-1430.	Ireland	1996-2005	TFP as residual from output regression, robustness using ACF. Also use labour productivity. Two-stage approach.	Six mutually exclusive categories: firms that do not trade, firms that export only, firms that import only, firms that e and import, domestic firms with intra-firm trade, and foreign-owned firms with intra-firm trade.	Linear regression with firm fixed effects and simultaneous quantile regressions for heterogeneous effects	Considers the link between importing and exporting
Aristei, D., Castellani, D., & Franco, C. (2013). Firms' exporting and importing activities: is there a two-way relationship? *Revie w of World Economics*, *149*(1), 55-84.	27 Eastern Europea n and Central Asian countrie s	2002 – 2008	Labour productivity (sales per workers)	Importing and exporting	A bivariate probit of exporting and importing as a function of previous import and export status	Consider the link between importing and exporting
Bas, M., & Strauss-Kahn, V. (2014). Does importing more inputs raise exports? Firm-level evidence from France. Review of World Economics, 150(2), 241-275.	France	1996-2005	TFPR (OP extended by ACF and modified to account for the fact that investment decisions depend also on the input-importing behaviour of the firm).	Imports variety: number of imported inputs. Also impact on exports.	Use firm-level import tariffs as an instrument for imports. Input tariffs are constructed combining data on imports with output tariffs. Single-equation approach.	Consider the link between importing and exporting
Colantone, I., & Crinò, R. (2014). New imported inputs, new domestic products. Journal of International Economics, 92(1), 147-165.	25 Europea n countrie s	1995 – 2007	share of new domestic products in the total number of domestic goods	share of new foreign varieties in the total number of imported input varieties	Instrumental variable regressions. Changes in transportation costs, as induced by fluctuations in oil prices as exogenous shocks to imports	Consider the impact of increased variety of imported inputs

Notes: TFP stands for total factor productivity; ACF stands for Ackerberg, Caves and Frazer (2015); OP stands for Olley and Pakes (1996).

Table 4: Studies on the relationship between exporting, importing and productivity (part III)

Title	Country	Period	Productivity measure	Trade measure	Method	Reason for inclusion
Powell, D., & Wagner, J. (2014). The exporter productivity premium along the productivity distribution: evidence from quantile regression with nonadditive firm fixed effects. Review of World Economics, 150(4).	Germany	1995-2010	Labour productivity (sales per workers). Adjusted to express it as the percentage relative to the 4-digit industry productivity mean.	Export participation	Quantile regression after conditioning on firm fixed effects	Consider exporter premium depending on the position of a firm in the productivity distribution.
Halpern, L., Koren, M., & Szeidl, A. (2015). Imported inputs and productivity. Americ an Ec. Review, 105(12), 3660-3703.	Hungary	1993-2002	TFPR using OP method modified by DL2011	Imports variety	Structural model.	Consider complementa rity between imported inputs
Harris, R., & Moffat, J. (2015). The impact of exporting and importing goods and services on productivity in the UK. The World Economy, 38(11).	UK	2011-2012	Output (sales) - TFP	Exporting and importing dummies	Matching on observables (propensity score matching). Augmented production function (one-step approach)	Consider entry cost complementa rities between importing and exporting
Benkovskis, K., Masso, J., Tkacevs, O., Vahter, P., & Yashiro, N. (2020). Export and productivity in global value chains: Comparative evidence from Latvia and Estonia. Rev. World Economics, 156(3), 557-577.	Estonia, Latvia	2006-2015, 1995-2014	TFPR (DL2013).	Export participation (entry)	To address the self-selection, employs the Propensity Score Matching. Then Difference in differences. Two-stage approach.	Consider if position in the value chain matters for the learning-by-export effect.
Bloom, N., Manova, K., Van Reenen, J., Sun, S. T., & Yu, Z. (2021). Trade and management. Rev. of Ec. and Stat., 103(3), 443-460.	Chinese and American firms	1999-2008 (China) 2010 (USA)	Exporting (status and revenues) and TFPR (using LP)	Management quality	OLS regressions with sector and location fixed effects. Two-stage approach.	Consider selection into exporting and Management competence.

Koch, M., Manuylov, I., & Smolka, M. (2021). Robots and firms. The Economic Journal, 131(638), 2553-2584.	Spain	1997-2016	TFP (DL2013), includes dummy indicating whether a firm uses robots to explain productivity dynamics	Export status	Linear regressions of export status interacted with robot	Consider the role of scale of export operations for innovation

Notes: TFPR stands for revenue total factor productivity; OP stands for Olley and Pakes (1996); DL2011 and DL2013 stands for de Loecker (2011 and 2013); LP stands for Levinsohn and Petrin (2003)

Table 5: Studies on the relationship between exporting, importing and productivity (part IV)

Title	Country	Period	Productivity measure	Trade measure	Method	Reason for inclusion
Aghion, P., Bergeaud, A., Lequien, M., & Melitz, M. J. (2022). The heterogeneous impact of market size on innovation: evidence from French firm-level exports. The Review of Economics and Statistics, 1-56.	France	1994-2012	Patents	Export-demand shocks	First-differences. Exogenous firm-level measure of export demand shocks (shift-share instrument) to avoid export-induced adjustments. Negative binomial regression to address presence of zeros	Consider the relationship between exporting and innovation
Mayer, T., Melitz, M. J., & Ottaviano, G. I. (2021). Product mix and firm productivity responses to trade competition. Review of Economics and Statistics, 103(5), 874-891.	France	1995-2005	Labour productivity (deflated value added per worker)	Export-demand shocks	First-differences,	Consider how exporting affects choice of products and productivity
Damijan, J. P., Konings, J., & Polanec, S. (2014). Import churning and export performance of multi-product firms. The World Economy, 37(11), 1483-1506.	Slovenia	1994-2008	TFP (OP including export and import dummy)	Firms that simultaneously import and export (trade flow pass through)	Regress TFP on number of imported intermediate, unit value and tariffs	Consider the link between importing Inputs, product churning and productivity

Eaton, J., Kortum, S., & Kramarz, F. (2011). An anatomy of international trade: Evidence from French firms. Econometrica, 79(5), 1453-1498.	France	Unknown	Labour productivity	Exporting, Number of destinations		Consider selection into exporting and choice of destinations
Turco, A. L., & Maggioni, D. (2013). On the role of imports in enhancing manufacturing exports. The World Economy, 36(1), 93-120.	Italy	2000-2004	Probability of exporting	TFP (based on index number) and imports of intermediates from low- and high-income countries over total intermediate inputs	Linear probability model looking at the probability of exporting	Consider cost savings from importing cheap intermediates
Muûls, M., & Pisu, M. (2009). Imports and Exports at the Level of the Firm: Evidence from Belgium. World Economy, 32(5), 692-734.	Belgium	1996-2004	Labour productivity and TFP (LP)	Importing/exporting	Descriptive statistics and regression analysis	Consider the relationship between exporting and innovation

Notes: TFP stands for total factor productivity; OP stands for Olley and Pakes (1996); LP stands for Levinsohn and Petrin (2003)

Table 6: Literature on supply chain disruptions and exports

Title of paper	Topic of paper	Country	Period	Data	Method	Results	Limitations	Reason for inclusion
Joussier, R., J. Martin and I. Mejean (2022), "Supply Shocks in Supply Chains: Evidence from the early lockdown in China," IMF Ec. Rev, May 2022.	Studies the impact of the early-2020 Covid lockdown in China on French firms sourcing inputs from China and the subsequent impact on those firms' exports and domestic sales.	France	2020	French customs data; INSEE-FARE data (balance sheet information for French firms); VAT statements of French firms.	The analysis consists of three parts. First, the authors try to establish whether the Chinese Covid lockdown led to a significant reduction in French intermediate goods imports by comparing firms that were sourcing intermediate inputs from China prior to Covid with those that did not; they then compare the evolution of exports and domestic sales for these two groups of firms; finally, the authors investigate whether a geographic diversification of input sources and the holding of inventories were effective in mitigating the impact of the Covid sourcing shock.	French firms sourcing inputs from China experienced a 7.4% drop in imports between February and June 2020 relative to firms that did not source from China. The exposed firms further experienced a 5.5% drop in domestic sales and a 5% drop in exports compared to non-exposed firms. Greater ex-ante diversification of input sources did not mitigate the negative impact of the Covid shock, but holding higher inventories did.	The study does not look at productivity effects and does not discuss issues of self-selection related to the fact that only certain types of firms might source from China.	Measures the impact of import disruptions on exporting.

Handley et al. (2020), "Rising Import Tariffs, Falling Export Growth: When Modern Supply Chains Meet Old-Style Protectionism." NBER Working Paper 26611.	examines the impact of the 2018-2019 U.S. import tariff increases on U.S. export growth	United States	2018-2019	confidential firm-level data containing information on US firms' trading activity and other standard firm-level information (employment, age, industry etc.)	regression analysis	The decline in export growth in 2019Q3, was equivalent to an ad valorem tariff on U.S. exports of 2% for the typical product and up to 4% for products with higher-than-average exposure.	very US-specific, results might be less applicable to other countries.	Measures the impact of import disruptions on exporting.

Table 7: Literature on supply chain disruptions and sales

Title	Topic of paper	Country	Period	Data	Method	Results	Limitations	Reason for inclusion
Carvalho, Vasco M, M Nirei and Y. Saito (2021), "Supply Chain Disruptions: Evidence from the Great East Japan Earthquake," Quarterly J. of Ec., vol. 136 (2), pp. 1255-1321.	Impact of the 2011 Japanese earthquake on the output of firms exposed to the disaster through supply chain connections.	Japan	2011	dataset on main customers and suppliers of firms.	regression analysis.	firms with disaster-hit suppliers observed a 3.8 %-points reduction in their sales growth rate, and firms with disaster-hit customers saw a 3.1 %-points decline in their sales growth rate.	does not look at the impact of supply chain disruptions on productivity.	Studies the effect of supply chain disruptions on firm sales.
Inoue, H. and Y. Todo (2022), "Propagation of Overseas Economic Shocks through Global Supply Chains: Firm-level Evidence," mimeograph, university of Hyogo.	Simulates the effects of supply chain disruptions in Japan.	Japan	2015-2020	Company Information Database and Company Linkage Database; IO table of Japan for 2015.	Agent-based model simulations.	Disruptions of imports of intermediate inputs increase rapidly with the duration of the supply shock, reaching 2.9% after four weeks and 26% after two months.	model does not allow for price reactions. Results are simulation results, not actually observed sales declines.	Studies the effect of supply chain disruptions on firm sales.
Boehm, C., A. Flaaen and N. Pandalai (2019), "Input Linkages and the Transmission of Shocks," Review of	Impact of the Tohoku earthquake on Japanese	United States	2007 and 2011	US Census bureau.	regression analysis,	Output of Japanese multinationals sourcing from	study is for the US, so might not	Studies the effect of supply chain

Economics and Statistics, vol. 101(1), pp. 60-75.	Multinationals in the US.					Japan fell because of the earthquake.	apply to other countries	disruptions on firm sales.

Table 8: Literature on supply chain disruptions and stock market performance

Title	Topic of paper	Country	Period	Data	Method	Results	Limitations	Reason for inclusion
Hendricks, K. B., & Singhal, V. R. (2009). An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm. *Production and Operations Management*, *14*(1), 35-52	Studies the long-run stock price effects of announcements of supply chain disruptions.	United States	1989-2000	Data on stock prices for firms listed on NYSE, AMEX and NASDAQ.	stock market event study	firms with SC disruption announcements experience lower abnormal returns (-40%) and increased equity risk in the year after the announcement.	Long-run event study; results likely to be sensitive to the choice of normal returns model.	Studies the effect of supply chain disruptions on stock market performance.

Table 9: Literature on the liberalisation of intermediate input tariffs

Title	Topic of paper	Country	Period	Data	Method	Results	Limitations	Reason for inclusion
Amiti, M. and J. Konings (2007), "Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia," American Economic review, vol. 97 (5), pp. 1611-1638.	Effects of reductions of tariffs on intermediate inputs.	Indonesia	1991-2001	annual manufacturing census.	Regression analysis.	A 10%-point fall in input tariffs leads to a productivity gain of 12%.	results specific to Indonesia, might not be applicable to a UK context.	Studies the effects of reductions of intermediate input tariffs.

Topalova, P. and A. Khandelwal (2011), "Trade Liberalization and firm productivity: The case of India," Review of Economics and Statistics, vol. 93(3), pp. 995-1009.	Effects of reductions of tariffs on intermediate inputs.	India	1987-2001	Prowess database.	Regressi on analysis	Reductions in output and intermediate input tariffs both increase firm-level productivity, but intermediate input tariff reductions have larger effects. Effects are strongest when tariff liberalization is accompanied by other industrial policy reforms.	results specific to India, might not be applicable to a UK context.	Studies the effects of reductions of intermediate input tariffs

Table 10: Research on the impact of changes in trade on UK productivity

Study	Topic	Methodology	Results	Limitations
Son (2021)	Examines how global trade expansion from 2002- 2011 affected R&D investment in 4,107 UK firms in manufacturing sectors	Firm-level R&D expenditure is modelled as a function of time-lagged industry-level Chinese import competition (Chinese import competition in other high-income economies as an instrument), time lagged firm-level export demand, as well as time lagged firm level imports, other control variables and various fixed effects.	UK firms' R&D spending falls by approximately four percent for every percentage point rise in the exposure to Chinese import competition. Increased access to Chinese imports for firms did offset the negative effect of Chinese competition. Conversely, UK firms' R&D spending increases by around six percent for every one unit increase in export demand. More productive firms that had already entered the export market were also better poised to take advantage of increasing foreign demand.	Focuses on R&D expenditure as a response variable, rather than productivity. Researchers also use log (x +1) for R&D expenditure. As this is often zero, results are scale dependent.
ESCoE (2018) and ONS (2018)	Analyses the link between productivity and goods trader status amongst a large sample of UK businesses across sectors between 2008 and 2016.	Descriptive statistics and linear regression. Approximate gross value added per worker is modelled as a function of exporter / importer status and various control variables.	UK businesses which declare international trade in goods were around 70% more productive on average than non-traders in 2016. Businesses which report goods exports or imports were around 21% and 20% more productive respectively than businesses which do not trade after controlling for their size, industry, and ownership status; among traders, more productive businesses export more products and import from more destinations than less productive traders.	Specifications fail to account for endogeneity. This study focuses on goods trade only, thereby excluding services trade.
Harris & Moffat (2015)	Uses UK plant-level data from 2011 and 2012 to estimate the impact of exporting and importing goods and services on total factor productivity (TFP).	Propensity score matching used to develop a sample of like firms. Real gross output is then modelled as a function of employment, intermediate inputs, capital stock, control variables and a series of dummies reflecting importer /exporter status.	Plants in manufacturing, services and wholesale and retail that import *and* export produce more (8.8%, 5.9% and 6.3%, respectively) than equivalent non-trading plants, controlling for various inputs and other variables.	Limited panel due to data availability. Selection problems are only partially addressed.

Harris & Li (2012)	Assesses the productivity impact of export-market transitions in both UK production and service sectors, covering the 1996–2004 period.	Real gross output is modelled as a function of employment, intermediate inputs, tangible assets, and export-market transition dummies, with age and possession of intangible assets used as part of an instrument set.	New exporters enjoy a 22% increase in TFP in the year of entry (10.5% in production industries and 37.2% in services). Meanwhile, firms exiting overseas markets experience a 15% decrease in TFP (19% in production industries and 8.9% in services).	Only focuses on the impact of exporting.
Kneller and Pisu (2010)	Uses survey data on UK firms (between 2003 and 2005) to explore benefits to exporting	Qualitative survey data and descriptive statistics.	Of the firms surveyed, 63.5% reported increased profits because of exporting, while 47.4% reported increased efficiency (the closest to a direct measure of productivity among the survey questions).	Subject to self-reporting, while the measure of "efficiency" may also be subject to interpretation bias.
Rizov and Walsh (2009)	Estimates the productivity dynamics of both exporters and non-exporters, within four-digit UK manufacturing industries from 1994-2001	An adapted algorithm is used to estimate the parameters of production functions for exporting and non-exporting samples of companies.	During the first years after the implementation of the Euro, improvements in aggregate productivity in UK manufacturing were a result of both market share reallocation and within-company productivity growth, including within-company improvements in the non-exporters' productivity.	Limited to manufacturing firms. Somewhat limited to the unique context of the implementation of the Euro.
Crespi et al. (2008)	Assesses the learning-by-exporting- ting hypothesis on results from the UK Community Innovation Survey which covers manufacturing and services firms over three periods (1994-1996-1998-2000)	Linear regression, cross section, and firm fixed effects, with lagged explanatory variables. With some falsification tests.	Firms that choose to export are 24% more productive than non-exporting peers in the two years before exporting. Exporters are a further 25% more productive than non-exporting peers in the two years after exporting. Past exporting is also positively associated with learning from buyers.	There are significant data requirements to measure "learning" - survey results are reliant on self-reporting.
Greenway et al. (2007)	Draws on a panel of 9292 UK manufacturing firms over the period 1993–2003 to explore the links between firms' financial health and their export market participation decisions.	Linear probability model. Probability of exporting.	Exporters exhibit better financial health than non-exporters. Moreover, there is strong evidence that participation in export markets improves firms' financial health.	Focuses on propensity to export, productivity is of secondary interest.

Table 11: Studies on productivity measurement (part I)

Title	Measure of productivity	Standard variables	Additional data	Method	Reason for inclusion
Breinlich, H., & Criscuolo, C. (2011). International trade in services: A portrait of importers and exporters. Journal of International Economics, 84(2), 188-206.	Total factor productivity (TFP)	Value added (or revenues), capital stock, number of employees, cost of material, sector classification	None	Residual from output or valued added regression. Can also be estimated in deviations from 3-digit sectoral medians.	TFP is the unexplained component of an output function.
Olley, G., & Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment industry. Econometric a, 64(6), 1263-1297.	Total factor productivity (TFP)	Revenues or value added, employment or labour costs, assets, sector classification, sector-level deflator	Non-missing investment: panel data (uses lagged variables)	Control function approach (two-steps). Investment policy functions are monotonic in capital and productivity. The investment policy function can be inverted to proxy unobserved productivity by a function of investment and capital, which is then substituted into the production function.	Method corrects for unobserved productivity shocks using investment expenditure. Use investment to proxy for productivity. It can deal with the bias due to exit of less productive firms.
Levinsohn, J., & Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. The review of Economic studies, 70(2), 317-341.	Total factor productivity (TFP)	Revenues or value added, employment or labour costs, assets, sector classification, sector-level deflator	Non-missing material expenditure (or electricity); panel data (uses lagged variables)	Control function approach (two-steps). Build on OP using primary input demand instead of the investment decision to control for unobserved productivity shocks.	Method corrects for unobserved productivity shocks using input expenditure (material or electricity)
Ackerberg, D. A., Caves, K., & Frazer, G. (2015). Identification properties of recent production function estimators. Econometrica, 83(6), 2411-2451.	Total factor productivity (TFP)	Revenues or value added, employment or labour costs, assets, sector classification, sector-level deflator	Non-missing material expenditure (or electricity) or investment; panel data (uses lagged variables)	Control function approach (two-steps). Proposes modification of OP/LP that avoids possible collinearity in the first stage in methods.	Method corrects for possible collinearity between labour and unobserved productivity in the first stage.

De Loecker, J., & Warzynski, F. (2012). Markups and firm-level export status. *American economic review*, *102*(6), 2437-71.	Total factor productivity (TFP)	Revenues or value added, employment or labour costs, assets, sector classification, sector-level deflator	Non-missing material expenditure (or electricity) or investment. Importer or exporter status; panel data (uses lagged variables). Physical output or price indices at product level.	The approach relies on estimating output elasticities of a variable input to calculate markups.	Method generates both productivity and markups, while controlling for potentially endogenous productivity improvements as a result of past export participation. This approach is being re-examined.

Table 12: Studies on productivity measurement (part II)

Title	Measure of productivity	Standard variables	Additional data	Method	Reason for inclusion
De Loecker, J. (2011). Product differentiation, multiproduct firms, and estimating the impact of trade liberalization on productivity. Econo metrica, 79(5), pp. 1407-1451.	Total factor productivity (TFP)	Revenues or value added, employment or labour costs, assets, sector classification, sector-level deflator	Non-missing material expenditure (or electricity) or investment; Importer or exporter status; panel data (uses lagged variables). Products produced by firms (can be proxy by 6-digit level sector classification)	Additional variables are included in the OP/LP approach. These are: quantity indices at the product level and product level dummies	Method separates demand (markups) and supply effect (productivity) by including product-level demand shifters.
De Loecker, J., & Warzynski, F. (2012). Markups and firm-level export status. *American economic review*, *102*(6), 2437-71.	Total factor productivity (TFP)	Revenues or value added, employment or labour costs, assets, sector classification, sector-level deflator	Non-missing material expenditure (or electricity) or investment; Importer or exporter status; panel data (uses lagged variables). Physical output or price indices at product level.	The approach relies on estimating output elasticities of a variable input to calculate markups.	Method generates both productivity and markups, while controlling for potentially endogenous productivity improvements as a result of past export participation. This approach is being re-examined.
De Loecker, J. (2013). Detecting learning by exporting. American Economic Journal: Microeconomics, 5(3), 1-21.	Total factor productivity (TFP)	Revenues or value added, employment or labour costs, assets, sector classification, sector-level deflator	Controlling for output and employment, the capital coefficient is expected to be biased given the strong correlation between a firm's export status and its level of capital stock.	Include lagged export status as determinant of productivity within an OP/LP approach.	Method deals with the fact that the decision of investing and exporting might occur simultaneously.

Notes: OP stands for Olley and Pakes (1996); LP stands for Levinsohn and Petrin (2003)

Table 13: Studies on productivity measurement (part III)

Title	Measure of productivity	Standard variables	Additional data	Method	Reason for inclusion
Collard-Wexler, A., & De Loecker, J. (2021). Productivity and Capital Measurement Error. NBER Working Paper.	Total factor productivity (TFP)	Revenues or value added, employment or labour costs, assets, sector classification, sector-level deflator	Non-missing material expenditure (or electricity) or investment; Importer or exporter status; panel data (uses lagged variables)	IV approach: the replacement value of capital and lagged investment as instruments for capital.	Method deals with measurement error in capital and the standard simultaneity bias due to unobserved productivity shocks.
Doraszelski, U., & Jaumandreu, J. (2018). Measuring the bias of technological change. Journal of Political Economy, 126(3), 1027-1084.	Total factor productivity (TFP)	Revenues or value added, employment or labour costs, assets, sector classification	Firm-specific prices for outputs and inputs, R&D expenditure.	Paper estimates a CES production function with two forms of productivity shocks (1) labour augmenting and (2) Hicks neutral.	Method considers that technological change can be biased towards a given factor but does not suggest method to estimate TFP.
Bloom, N., Sadun, R., & Van Reenen, J. (2016). Manage ment as a Technology? (N o. w22327). National Bureau of Economic Research.	Total factor productivity (TFP)	Value added (or revenues), capital stock, labour costs, cost of material, sector classification	None	Solow residual. TFP is calculated by deducting ln(labour) and ln(capital) from ln(value added) using three-digit industry- specific shares in nominal value added as weights for the factor inputs. Assumes perfect competition in the input and output market.	Method measures productivity as a residual. Weights are obtained from descriptive statistics rather than regression analysis.
Lileeva, A., & Trefler, D. (2010). Improved access to foreign markets raises plant-level productivity… for some plants. The Quarterly journal of economics, 125(3), 1051-1099.	Labour productivity (LP)	Value added (or revenues), number of employees.	None	Simple log of ratio of value added (or sales) over employees	Method does not require estimating but increases could be driven by capital accumulation.
Bloom, N., Sadun, R., & Van Reenen, J. (2016). Manage ment as a	Management quality	Tailored management survey	Specific management-related questions (double blind, managers are	Management practices are scored from one ("worst practice") to five ("best	Method considers management competence as a key component of TFP; effective

Technology? National Bureau of Economic Research Working Paper 22327			unaware of being scored).	practice"). Average score.	managerial practices increase both production efficiency and quality capacity. Management practices are considered a concrete, tangible and directly observed measure of TFPQ.

Table 14: Studies on productivity measurement (part IV)

Title	Measure of productivity	Standard variables	Additional data	Method	Reason for inclusion
Lileeva, A., & Trefler, D. (2010). Improved access to foreign markets raises plant-level productivity… for some plants. The Quarterly journal of economics, 125(3), 1051-1099.	Labour productivity (LP)	Value added (or revenues), number of employees.	None	Simple log of ratio of value added (or sales) over employees	Method does not require estimating but increases could be driven by capital accumulation.
Aghion, P., Bergeaud, A., Lequien, M., & Melitz, M. J. (2018). The heterogeneous impact of market size on innovation: evidence from French firm-level exports. The Review of Economics and Statistics, 1-56.	Innovation	R&D expenditure, patents	Data on patents or data on R&D expenditure matched to firm-level data	Dividing the change in patent stock – new patents introduced between t and t−1 – by the average stock in those 2 periods, New patents alone and controlling for stock in the regression. Should adopt estimation technique that can deal with many zeros in the outcome variable	Method considers that productivity captures the efficiency of the production process while innovation generates changes in efficiency. Although innovation does not always lead to productivity gains, it is a key determinant of productivity

5.2.1 Measures of productivity

The literature review has identified three main measures of firm-level productivity (***Figure 8***). This section provides the following details for each of the measures of productivity: what the measure captures (rationale), the data requirements, the limitations and examples of studies that have employed such measure.

A1. Labour productivity

Rationale: Labour productivity is the simplest measure of productivity as it does not require estimating a production function and has minimum data requirements compared to other measures. Labour productivity is commonly measured by the logarithm of deflated value added per worker or sales per worker.

Data requirements: Value added or sales, and the number of employees. It can be used with cross-sectional data.

Limitations: While this measure does not require assumptions, it has the drawback that observed increases in productivity could be driven by capital accumulation rather than efficiency gains or technological change.

Examples: papers that have used labour productivity to estimate the impact of trade on firm-level productivity include Crespi et al. (2008), Lileeva and Trefler (2010), Breinlich and Criscuolo (2011), Aristei et al. (2013), and Powell and Wagner (2014).

A2. Total factor productivity

The literature on the measurement of total factor productivity is quite developed. All measures of TFP require data on deflated sales (or value added), assets, and employment. Besides this minimum data requirement, different methods can require additional data, as further described below.

A2.1 TFPQ vs TFPR

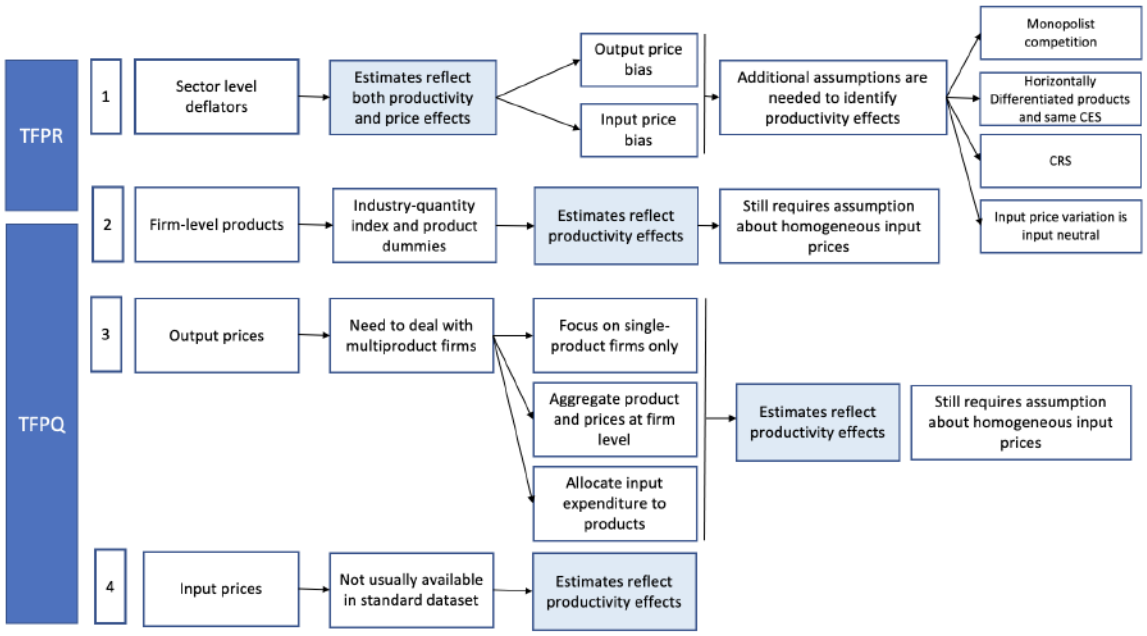
Depending on the availability of price data, TFP can be distinguished into physical productivity (TFPQ), which uses firm-level deflators, and revenue productivity (TFPR), which uses sector-level deflators. TFPQ is considered a good proxy for technical efficiency, as it is the closer approximation to how much output can be obtained from given inputs. TFPR instead captures both technical efficiency and markups. This is because the output is proxied by revenues and conflates both quantities and price changes.

While traditional measures of TFPR and TFPQ are highly correlated, TFPR tends to overestimate the productivity of firms producing higher price products while underestimating that of firms producing lower-price (quality) products, since real sales are obtained by using the same deflator for all firms in the same sector. De Loecker and Goldberg (2014) provide a useful overview of the assumptions needed to estimate productivity effects depending on price data availability, which is summarised in ***Figure 9***.

The use of sector-level deflators instead of firm-level prices implies that productivity estimates (TFPR) capture both productivity and price effects (see Row 1 of ***Figure 9***). More specifically, there are two possible price distortions (biases). First, because output prices are correlated with input use (firms charging higher prices, produce lower quantity and use fewer inputs), omitting output prices causes a bias in the estimating of the input coefficients (output price bias). Second, because firms with higher input prices will have higher input expenditures that will not lead to higher physical output, omitting input prices also causes a bias in estimating the input coefficients (input bias). This implies that in the absence of additional data, strong assumptions are needed to estimate productivity effects. These are: 1) the industry is characterised by monopolistic competition. 2) Firms produce horizontally differentiated products and face the same constant elasticity of substitution (CES) demand system. 3) Production is characterised by constant returns to scale (CRS). 4) Input price variation (across firms and time) is input neutral. Despite these limitations, TRPR is still a widely used measure of productivity. See, for example, the studies by Bas and Strauss-Kahn (2014), Halpern et al. (2015) and Bloom et al. (2021).

When information on firm-level products is available, De Loecker (2011) shows that output price bias can be addressed even with standard data in which output and input prices are not observed (see Row 2 of ***Figure 9***). This is achieved by augmenting the production function with an industry quantity index and a set of product dummies. The method accommodates multi-product firms, but still requires the assumption of homogenous input prices.

Figure 10: Data requirements and assumptions for TFPR and TFPQ



Note: CRS stands for constant return to scale assumption. CES stands for constant elasticity of substitution.

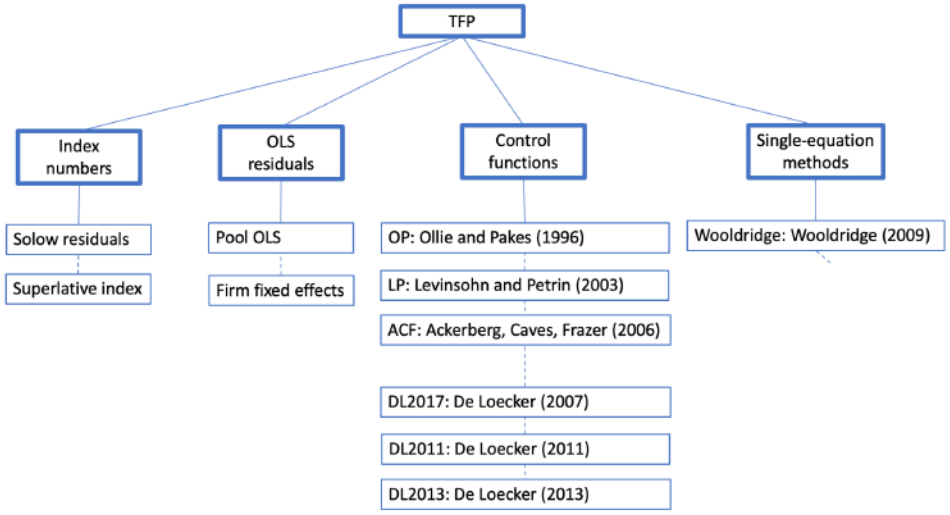
When output prices are available in firm-level data, they can be used to convert revenues into quantities and obtain productivity estimates that do not reflect price changes. However, such estimates are still conditional on the assumption of homogenous input prices and are subject to some additional methodological steps (see Row 3 in ***Figure 9***). The main challenge is dealing with multiproduct firms, as unit prices reflect differences in the units in which quantities are recorded across firms and products. This has been addressed in various ways. First, by focusing on single-product firms only, such as in the case of Foster et al. (2008) who look at firms producing ready-mixed concrete. This is very restrictive, and results might not be easily generalised to other types of firms. A second option is to aggregate product prices to the firm level and conduct the analysis at the firm level. A third option would be to allocate firm input expenditures to individual products and conduct the analysis at the product level, which however requires assumptions on how to allocate input expenditures across products.

Finally, having access to input-level prices could further help relax the assumption about homogenous input prices (Row 4 of ***Figure 9***). However, firm-level datasets rarely contain information on intermediate input prices. One notable exemption is a dataset of Colombian firms used in Kugler and Verhoogen (2012).

A2.2 Methods to estimate TFP

There are four main methods to estimate TFP. **Figure 10** describes the rationale underlying each method, the data requirement, and the methods' limitations, and provides examples of their application.

Figure 11: Main methodologies to estimate TFP



Index numbers

These are the least demanding methods to compute TFP in terms of data availability and quality. They can be computed using simple sample statistics. The two most widely index measures are the Solow residuals and the Superlative index.

Rationale: These measures simply relate output or value added, if available, to a weighted sum of inputs. The indices are obtained by deducting the cost of labour (in logs) and the cost of capital (in logs) from the value added (in the log). Weights are computed using the shares of each input to value-added. For the Solow residual, the shares are averaged within an industry, while for the Superlative index, the shares are firm-specific.

Data requirements: Value added (or sales), wages, and assets. Sector classification at 2-digit level or above. Can be used with cross-sectional data.

Limitations: These measures imply constant returns to scale, as they assume that the ratio of outputs to inputs is constant. Being less empirically rigorous, these measures are usually used as a secondary measure for robustness checks.

Examples: Bloom et al. (2016) and Gal (2013). The latter paper shows that this method can be employed to estimate TFP using Orbis Bureau Van Dijk data for Great Britain and provides guidelines on how to impute data where there are missing values.

OLS residuals

This is the simplest approach that relies on regression analysis.

Rationale: This method typically assumes that output (sales or value added) is a function of a firm's inputs and productivity. TFP is measured as the residual from OLS regressions that estimate the production function using firm-level data. This is usually done by running separate regression for each industry. When a panel of firms is available, firm fixed effects are usually included to account for unobserved differences across firms (unobserved heterogeneity).

Limitations: the coefficients obtained from OLS estimates are likely to be biased. For example, firms with higher productivity are likely to hire more workers. Since productivity enters the error term as it is not directly observed, this causes a problem of omitted variable bias (i.e., the coefficient of labour in the production function is likely upward biased). While fixed effects can control for time-invariant unobservable, the concerns remain for unobserved productivity shocks.

Data requirements: Value added (or sales), wages, assets, and material costs (optional). Panel data (also short panels as variables are not lagged). Sector classification at 2-digit level or above. Can be used with cross-sectional data.

Examples: In Haller (2012), OLS residuals were used as the main measure of productivity because having to rely on lagged values, as required by other methodologies, would have implied the loss of a significant share of observations. Other examples include Breinlich and Criscuolo (2011).

Control functions

These methods aim at addressing the omitted variable bias problem that affects OLS estimations of TFP. These methods are two-stage approaches that explicitly model the unobserved productivity shocks.

Rationale. There are three main variations of the control function approach and a set of extensions. The main intuition behind these approaches is that the endogeneity problem discussed above is caused by the fact that productivity is unobserved by the econometrician. If it is possible to write an equation explaining productivity (i.e., making it "observable"), then the endogeneity problem could be eliminated. The first approach is proposed by Olley and Pakes (1996), known as OP, who use a firm's investment (proxy variable) to inform about productivity shocks.[61] The second approach is by Levinsohn and Petrin (2013) and is known as LP. The authors worry that the use of investment as a proxy variable is only valid for firms reporting non-zero investments.[62] However, often firms do not

[61] *Investment is modelled as a function of capital and productivity. By inverting the investment function, they obtain an expression for the productivity shock in terms of investment and capital. This expression is then substituted into the production function to account for productivity shocks.*
[62] *They also worry about the assumption in Ollie and Pakes (1996) that any two firms with the same level of capital and investment must face the same productivity shocks.*

always incur investment expenditure, especially in developing countries. Hence, they suggest using intermediate inputs expenditure, instead of investment, to learn about productivity shocks. Both OP and LP assume that firms can instantly adjust some inputs at no cost when subject to productivity shocks. However, in the third approach by Ackerberg et al. (2015), known as ACF, the authors note that the labour coefficient can be consistently estimated in the first stage only if the free variables, i.e., labour, show variability independently of the proxy variable, i.e., either investment or material costs. If this is not the case, a collinearity problem arises, and the input coefficients cannot be correctly estimated. The authors propose a correction that addresses these concerns, where all coefficients are estimated in the second stage.

Extensions: There are three notable extensions of the control function methods described above. First, De Loecker (2007, 2013) suggests using lagged export status as an additional driver of productivity dynamics within the OP/LP approach. Following this, other papers have included lagged importing status (Bas and Strauss-Kahn, 2014) or both importing and exporting status (Damijan et al., 2014) as drivers of productivity. This set of extensions allows for the fact that expenditure/investment decisions are also likely to depend on the exporting/exporting behaviour of the firm. Another extension is proposed by De Loecker (2011) and requires augmenting the production function with an industry quantity index and a set of product dummies. Note that for this extension, data on the products produced by firms are needed. This extension allows the researcher to separate productivity from price effects, as described above.

Limitations: Control function approaches can be computationally demanding, especially when dealing with large datasets, as they require bootstrapping of standard errors. In addition, the methods are not consistent if input expenditures are measured with error.

Data requirement: Value added (or sales), wages, assets. In addition, either data on material costs or non-zero investment expenditures are necessary. Sector classification at 2-digit level or above. A panel dataset is needed, and longer panels are preferred since the method used lagged variables. Extensions might require additional data.

Examples: This is one of the most popular approaches to estimating TFP, hence there are several examples in the literature. Besides those mentioned above, the method is also used by Greenaway et al. (2007), Aw et al., (2011) and Bloom et al., (2016), among others.

Single-equation method

An alternative method to estimating TFP is proposed in Wooldridge (2009). This method is based on estimating productivity in a single step, using a system generalised method of moments (GMM) econometric framework.

Rationale: Wooldridge (2009) shows that OP and LP methods can be implemented in a single-step generalised method of moments (GMM) estimation method, which overcomes the identification problems identified by Ackerberg et al.(2015) and improves standard errors.

Limitations: This method uses lagged variables, and it can be costly in terms of sample size as each additional lag implies the loss of observations during the estimation. Mollisi and Rovigatti (2017)provides a solution that works better with short panel data.

Data requirement: Value added (or sales), wages, assets. In addition, either data on material costs or non-zero investment expenditure are necessary. Sector classification at 2-digit level or above. A panel dataset is needed, and longer panels are preferred since the method used lagged variables.

Examples: Despite being equally rigorous as the control function approaches, this method has been less used in empirical papers. Among the papers considered in this report, DeLoecker (2011) adopt the method for comparison with alternative approaches to look at the impact of abolishing quota protections on productivity. Battisti et al. (2021) adopt this methodology to estimate TFP across 15 EU countries to look at its relationship with firm internationalisation status.

A3. Indirect measures of productivity

Indirect measures of productivity include management quality and innovation.

Rationale: Management competence is considered a key component of total factor productivity, as effective managerial practices have been found to increase both production efficiency and quality capacity (Bloom et al., 2016). One of the advantages is that management practices can be considered a concrete, tangible and directly observable measure of TFPQ that can circumvent estimation concerns. In addition, it also allows for delivering clear policy recommendations. Innovation has also been linked to productivity. More specifically, while productivity measures aim at capturing the efficiency of the production process, innovation generates changes in efficiency. Hence, innovation is a key determinant of productivity, although innovation does not always lead to productivity gains (Aghion et al., 2018).

Limitations: one of the limitations of using these measures of productivity is that they are quite demanding in terms of data requirement (see below).

Data requirement: Management quality is measured with tailored surveys. Innovation can be measured by R&D expenditure, which is sometimes recorded by standard firm-level surveys, or by patents. In this latter case, patents need to be matched to firm level data, and this is only possible if firm identifiers are made available.

Examples: Examples of papers that have used innovation (patents or R&D expenditure) as a measure of firm performance are Aghion et al. (2022) who investigate the impact of exporting and Autor et al. (2020) who consider the impact of importing. Bloom et al (2021) have instead used measures of management quality to show that exporters are better managed firms.

5.2.2 How to estimate the impact of trade on productivity

There are two main approaches in the literature to estimate the impact of trade on productivity: the two-stage approach and the Single Equation Approach.

The two-stage approach. The first step involves estimating the production function to produce productivity estimates, ignoring trade related variables. Productivity estimates can be corrected for the simultaneity bias using the standard proxy approaches of OP/LP and ACF. The second stage projects the recovered "productivity" estimate against the shift in trade regime. This approach does not allow trade to impact the evolution of productivity when estimating the production function itself.

Examples: This is the most common approach in the literature. Examples include Haller (2012), Bloom et al. (2016), Benkovskis et al. (2020) and Koch et al. (2021).

The Single Equation Approach. This procedure starts out with specifying a parametric function for productivity in the variable of interest (i.e., export participation). This function for productivity is then substituted into the production function, generating an estimating equation that includes both inputs of production and trade specific variables. This approach allows for trade to impact the evolution of productivity when estimating the production function itself. This approach can also be incorporated into the OP/LP methodology by modifying the productivity process to include exporting/importing status in addition to investment/material expenditure.

Examples: Bas and Strauss-Khan (2015), Harris et al. (2015), Bigsten et al. (2004), Fernandes and Isgut (2005) and Van Biesebroeck (2005).

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