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Supply Chain Linkages with Foreign Multinationals: The Productivity Effects for Domestic Firms

Evidence from extrapolated Dutch inter-firm transaction data

Master Thesis Policy Economics

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Abstract

This paper studies the productivity effects for domestic suppliers and buyers that acquire linkages with multinational enterprises (MNEs) in the Netherlands. Statistics Netherlands developed an extrapolation method estimating firm-to-firm transaction data which is consistent with the input-output tables and recreates all stylized facts found in previous descriptive literature of non-extrapolated datasets. Leveraging this novel approach facilitates studying the network of domestic firms in a western economy using non-sector level variation. This deepens the understanding of the effects of globalisation. The model exploits a shock to the network caused by the Brexit that alleviates reverse causality concerns. The results indicate that the productivity of a domestic firm is positively correlated with a change in the amount of supplier linkages with MNEs. Similar to Alfaro-Ureña et al. (2022), first-time suppliers to MNEs are predicted to experience short-term capacity constraints that relax over time. The results further increase the confidence in the extrapolation and positive effects of foreign direct investment. This enhances the capacity of policymakers to access the impact of foreign direct investment.

I am grateful to Gert Buiten and dr. Arjen de Boer from Statistics Netherlands for providing the opportunity to study the data. My time at Statistics Netherlands was inspiring and gave me a lot of energy. The work environment they created gave plenty of room for fruitful discussions and stimulated creativity, for which I would like express my gratitude again. Moreover, I would like to thank everyone from Statistics Netherlands, CPB and Erasmus university for their comments and thoughts on my work. Last, special regards to Aksel Erbahar for the supervision and guidance of this masters thesis.

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1 Introduction

The Invest(in)Country.com[1] trend underscores the intense competition among governments to attract foreign direct investment (FDI) through a range of incentive structures, most commonly aimed at multinational enterprises (MNEs) or affiliates. Tax incentives, next to subsidies, are key to this approach, as illustrated by the proactive stance of the Dutch foreign investment agency: "The Dutch Tax Authorities have a flexible and practical approach, with a proactive attitude"[2]. Governments expect MNEs to be exceptional performers—stemming from predictions of the Melitz model (Kendall & Ryan, 2007; Mayer & Ottaviano, 2007)—anticipating an enrichment of the local business climate. Domestic firms are expected to benefit from spillovers created by MNEs. MNEs transform the operational dynamics of the domestic supplier firms by providing technologies, managerial expertise, market access, and technical assistance, thereby maximising the gains of the interaction (Alfaro-Ureña et al., 2022; Javorcik, 2004). Moreover, the mobility of workers from the more productive MNEs to domestic firms is believed to create spillovers for domestic firms (Setzler & Tintelnot, 2021). Therefore, the intensifying efforts of governments to attract FDI fosters the need for a greater understanding of the materialised gains of these expected spillover effects. Specifically, examining supply chain linkages from a domestic firm to a MNE is crucial, as this type of spillovers is believed to play a significant role in creating domestic productivity gains (Havránek & Iršová, 2011).

The rich literature on this topic provides solid direction, but lacks findings on direct linkages on a, near economy wide, micro level. This is due to the illusive nature of observing actual supply chain linkages between business which inhibited literature to paint a complete picture. Most past research has thus relied on sector- or sector-by-region-level variation using the degree of foreign ownership in downstream sectors to uncover the effect of supply chain linkages (Alfaro-Ureña et al., 2022; Havránek & Iršová, 2011). Nevertheless, Alfaro-Ureña et al. (2022) provide convincing causal evidence, using a near universe of formal firm-to-firm transactions dataset in Costa Rica, that first-time domestic suppliers to MNEs experience strong and persistent gains in firm performance. Nonetheless, the results are yet to be replicated in developed economies.

This papers aims to empirically investigate the relation between the productivity of domestic firms and the presence of (foreign) MNEs in an economy. Specifically, investigating direct supply chain linkages between MNEs and domestic firms and the difference in productivity effects between being a supplier or buyer to a MNE as a domestic firm. Thus,

[1] Most countries have a web-domain in the specified structure

[2] Quote found on: https://investinholland.com/why-invest/incentives-taxes/

this paper aims to answer the following question: **Are there any productivity spillovers from MNEs to domestic firms via supply chain linkages?**

The main analysis consists of analysing the productivity effects of MNEs to domestic firms through direct linkages with MNEs. [3] The dataset contains several rich micro-datasets from the Netherlands provided by Statistics Netherlands (Centraal Bureau voor de Statistiek). The network data is created using an experimental algorithm[4] which partially extrapolates the linkages using firm characteristics and observed linkages resulting in a total of 17.987.460 inter-firm linkages. This is complemented by a large set of 53.206 domestic firms spanning from 2018 to 2020, yielding 141.466 observations. This data allows for the analysis of the effect of a change in the number of buyer or supplier linkages on the productivity of domestic firms.[5] The aim of this paper is to confirm claims of positive spillover effects of linkages by previous literature (Havránek & Iršová, 2011), making use of sector level variation, by leveraging the ability to observe micro linkages between firms in a non-survey setting.

The analysis is set-up in the following manner. First, this research leverages the business network data from Buiten et al. (2021) with firm characteristics to replicate stylized facts observed in the literature. Second, the number of (MNE) suppliers and buyers are calculated for each firm, and the linkage data is aggregated as to compare the changes in domestic firms' productivity to its numbers of (MNE) supplier or buyer linkages. Third, it is estimated how a domestic firms' productivity depends on specific types of connections by calculating aggregated weights of each type of interaction, normalised by the sales of the domestic firm. Last, a shock to the network is leveraged, caused by firms that joined the Netherlands due to the Brexit, to analyse how the productivity of domestic firms is impacted by linkages with (former) foreign MNE when reverse causality issues are accounted for.

The identifying assumption of the base strategy requires that the number of linkages of each domestic firm is exogenous to its productivity. Besides omitted variable bias concerns there are reverse causality concerns. It is in a firms best interest to choose the most productive suppliers. Therefore, it is probable, and indicated by the results, that a change in the productivity of the domestic firm results in the firm getting more linkages, resulting in reverse causality. In an attempt to address the reverse causality, the main model leverages

[3] A MNE in this paper is defined as a firm that has at least one subsidiary outside of its headquartered country. A foreign MNE, besides following the MNE definition, additionally has an ultimate owner located in a country other than the Netherlands. The minimum required ownership percentage of this subsidiary is as of yet unknown to me. Following these definitions, the remaining firms are defined as domestic firms.

[4] See Buiten et al. (2021) for more details on the methodology of the algorithm

[5] To note, the data is analysed on 'business unit' level, the closest term to this is 'enterprise'. This paper uses the word 'firm' to refer to enterprises as technically one business unit can contain many firms.

variation from firms that changed ultimate owner from the United Kingdom to the Netherlands. The resulting linkages with these Brexit firms are argued to be independent of the change in productivity of the domestic firm. The entry of the Brexit firms is likely driven by economical shifts caused by Brexit, rather than changes in productivity by its potential suppliers or buyers. The estimations account for any time-invariant differences between firms and shocks common to firms in the same four-digit sector and region as in Alfaro-Ureña et al. (2022).

The extrapolated data appears to be consistent with the stylized facts of previous literature using non-extrapolated datasets, increasing the validity of the extrapolation method of Buiten et al. (2021). The results further show that domestic firms experience positive productivity effects from supplying a foreign MNE, aligning with the findings of previous literature. Also, for domestic firms increasing the dependency on foreign MNEs is positively correlated with its productivity, while increasing the dependency on domestic firms is negatively correlated in both supplier and buyer linkages. After a shock to the network like Brexit, domestic firms that engage with firms that changed ultimate owners from the United Kingdom to the Netherlands are estimated to gain productivity benefits. First-time MNE suppliers appear to face a transitory short-term productivity fall, reflecting short-term capacity constraints which again aligns with the findings of Alfaro-Ureña et al. (2022). Positive productivity effects of buying from foreign MNEs remain inconclusive. These results increase the confidence in positive productivity effects from supplying a foreign MNE.

The base results are robust to changing the method of productivity estimation with the baseline using total factor productivity using the Ackerberg et al. (2015) method and alternative methods using the growth method to calculate total factor productivity and labour productivity. The Brexit results are not robust to using alternative productivity measures which suggests that controlling for the endogeneity of the input factors as done in the productivity Ackerberg et al. (2015) method is crucial. Furthermore, a placebo test implies that the results are not due to spurious correlation.

This work relates to several strands of literature. This paper mainly adds to the foreign direct investment and firm performance literature by being one of few papers that use direct linkages between firms to estimate productivity effects and to my knowledge first in a developed Western economy. The usage of linkages offers a vast source of variation can be used to approximate a more precise estimate of the consequences of FDI compared to traditional sector level proxies of FDI. Next, this paper adds to the production network literature by showing that the extrapolation method of Buiten et al. (2021) yields stylized facts that are consistent with stylized facts found in observed —thus non-extrapolated —networks

presented by Alfaro-Urena et al. (2018), Bacilieri et al. (2023), and Bernard et al. (2022). Moreover, models using this methods appear to result in estimates which are in-line with previous literature which improves the confidence in the extrapolation method.

The results of this study are directly valuable for policy makers. Estimates of this study may be used to compare policy measures which aim to increase the FDI inflow against other use cases of tax payer money. Policymakers gain more insight into the importance of MNEs for the local business environment and the competitive position of domestic firms. This shows the importance of MNEs not only for the economy in a direct manner but also by indirectly introducing spillover effects. Last, policy makers in countries that do not lawfully enforce the registration of all transaction in an economy—which is costly—can better access the benefits of using extrapolation method to understand how shocks potentially affect their economy.

The paper is organised as follows. Section 2 develops the hypotheses using the relevant literature. Section 3 provides a full breakdown of the data and describes the data. Section 4 introduces the methodology and its identifying assumptions. Section 5 presents the baseline results and check the robustness of these results. Section 6 describes the limitations of the study. Section 7 concludes and provides avenues for future research.

2 Hypothesis development

This section aims to understand the impact of domestic firms' direct supply chain linkages with MNEs on the productivity of domestic firms. The multifaceted nature of this relationship requires insights from the FDI-, network reconstruction-, and the global value chain literature. The latter being important to understand the general essence of having direct supply chain linkages with MNEs. MNEs alter the dynamics of the firms they are supplied by—using their market power to enforce changes—as to maximise the gains of the interaction. Supplier choice strongly influences the productivity of a firm as input costs determine, to a vast extent, the marginal cost structure and the quality of a value chain.[6] Especially, if the inputs supplied are crucial to the core operations of the firm (Alfaro-Ureña et al., 2022). The willingness to improve the productivity of suppliers is often in the best interest of the MNE, as any improvements to their operations improves the operations of the MNE (Alfaro-Ureña et al., 2022). This potentially results in productivity spillover effects for domestic firms which offer a vast source of productivity gains. Thus, understanding these spillover mechanisms is required to paint a complete picture of the productivity effect of

[6]Bernard et al. (2022) lists a set of firm heterogeneity papers related to this claim.

supply chain linkages with MNEs.

2.1 Direct supply chain linkages

A conceptualization of which firms get to supply or buy from a MNE is key to understanding the gains of becoming a linked to a MNE. A recent series of papers about supply chain networks emerged describing stylized facts about production networks, offering insights into the MNEs' supplier dynamics. The stylized facts are used to extrapolate the reconstruction of networks (e.g. Buiten et al. (2021) and Mungo et al. (2023)). The dataset is derived from Buiten et al. (2021). Therefore, it is crucial to understand the assumptions and data of this paper as the results of this paper rely on them.

2.1.1 MNE's supplier choice dynamics

Krichene et al. (2018) study supplier-customer networks of listed Japanese firms. They estimate that firms rationally form connections based on sector of activity, geographical location and profit homogeneity. The authors supplement their findings with the following rationale. 1) Naturally, firms within the same sector are more likely to connect due to having similar interest and activities. Therefore, trade between these firms is made easier. 2) Firms are more likely to choose partners closer in geographical proximity due to the lower transport costs associated with the interaction.[7] Supplementary, Arkolakis et al. (2023) finds that in Chile, the number of buyers and suppliers not only correlates with firm size but also with geographic location. Dhyne and Duprez (2016) find that geographical distance remains a key determinant for inter-firm trade in equally small countries like Belgium. The authors find a striking similarity in the median distances found between Belgium and Japan making which makes it more convincing to assume that distance remains a significant determinant for the formation of supply chain networks. Thus, this paper assumes that this finding applies for the Netherlands. 3) High profit firms benefit from profit sender and receiver effects—profitable firms both contributing to and benefiting from interactions with firms—forming more connections overall, with low profit firms being more likely to be connected with these high profit firm. Highly profitable firms likely have a pivotal role in enhancing market efficiency in supplier and buyer networks as they amplify the ability for small firms to form connections.

[7]Bernard et al. (2019) use the opening of a Japanese high speed rail line to estimate that the increase in firm performance found, is associated with a change in the set of suppliers and sourcing locations. The paper provides evidence that decreasing the 'transport costs' result in an increase in face-to-face interactions which supplement the likelihood of finding a matching supplier, improving firm performance.

2.1.2 Business network characteristics

Bernard et al. (2022) further study a production network of Belgian firms and describe three stylized facts about production networks. 1) There is a high degree of dispersion in the number of buyers and suppliers, where firms both exhibit very small networks and very large networks which are magnitudes smaller or larger than the industry average. Moreover, Alfaro-Urena et al. (2018) show that productions networks follow a Pareto distribution in the number of connections, which implies that most firms have few connections. 2) There is a positive correlation between the number of connections and the size of a firm. In general, firms with more buyers have higher sales because they have more clients, not due to more sales per buyer.[8] Bernard et al. (2022) find that the bottom buyers of a firm are not systematically neglected relative to their top buyers when the number of buyers is expanded.[9] 3) Production network exert negative degree assortativity—firms with more connections connecting to less well-connected firms—on average (Antràs & Chor, 2022).[10]

2.2 Direct effects of MNE linkages

Alfaro-Ureña et al. (2022) explore the effects of a domestic firms becoming a first time supplier using a near universe of formal firm-to-firm transactions in Costa Rica. They exploit the timing of the event as they observe the year in which the transaction started, providing robust causal evidence. Four years after the event, domestic firms who become first time suppliers, on average, employ 26% more workers, have 33% higher sales, have 22% more net assets, and have 26% more input costs relative to the year before the event. Also, first-time suppliers of MNEs are estimated to experience a sizable and lasting gain in total factor productivity (TFP) of 4% to 9% four years after the event.[11] Contracts with MNEs, compared with domestic partners, often involve longer-term firm-to-firm relationships—stemming from larger transaction costs (Coase, 1995)—fostering trust between buyers and suppliers creating ample opportunities for exchanges of technology and knowledge (Alfaro-Ureña et al., 2022). It has to be noted that these effects are from a developing economy, namely Costa Rica, and

[8] Interestingly, also found in Alfaro-Urena et al. (2018), implying a striking resemblance between supply chain networks in developed and developing economies

[9] The authors find that the weighted average market share is declining with the number of buyers, which reliefs concerns of selection regarding if sellers selectively match with buyers when they grow their buyers base.

[10] Also found in production network describing Japan (Bernard et al., 2019), Costa Rica (Alfaro-Urena et al., 2018) and Norway (Bernard et al., 2018)

[11] Alfaro-Ureña et al. (2022) provide strong evidence that this increase is due to actual increases in productivity and quality but cannot exclude the full effect of a predicted subsequent increase in mark-ups.

that the results have as of yet not been replicated in more developed economies.

An exception is Masso and Vahter (2023) who use supplier network data of Estonian firms, propensity score matching strategy and difference-in-difference equation. The authors find a substantial increase in labour productivity of the supplying firm through increasing the scale or effects on capital intensity. However, the authors find that the subsequent TFP increase remain elusive in the initial stages of the linkage. The labour productivity effects appear to be limited to first-tier suppliers with direct linkages to MNEs which stresses the importance of direct MNE interactions for the diffusion of spillover effects (Masso & Vahter, 2023).

Interestingly, Alfaro-Ureña et al. (2022) find that domestic firms face a steep upward sloping short-run marginal cost curve after becoming a first-time supplier to a MNE. This is observed due to a resulting short-term fall in sales to other firms besides the MNE. The authors hypothesize that domestic firms experience capacity constraints or inflexibility of inputs. This implies that, first-time domestic suppliers of MNEs are required to adjust to the demands of the MNE. Conditional on the sectoral market share of the firm, firms that have larger input shares among buyers charge higher mark-ups which suggests that firms compete in an oligopoly to supply inputs to each buyer (Dhyne et al., 2022). The resulting changes in the behaviour of the domestic firms, due to supply chain linkage with MNEs, demonstrate the power that MNEs have on the cost and price structures of domestic firm. While adaptation cost may outweigh the initial gain in productivity in the early stages of the interaction, these cost are likely to diminish in the long-term due to the longer-term nature of contracts with MNEs. Thus, domestic firms are predicted to become more productive after becoming suppliers to MNE.

The evidence for productivity spillovers from forward linkages—domestic firms that are supplied by MNEs—is less conclusive. Earlier literature fails to find any correlation between the foreign presence in upward sector and productivity, proxing for forward linkages on a more aggregate level (Javorcik, 2004). An exception is found in Görg, Seric, et al. (2013) who does find a positive correlation between forward linkages and the labour productivity of domestic firms using data from 19 countries in Africa. Görg, Seric, et al. (2013) argues that domestic firm that bought from a MNE were able to implement the superior inputs resulting in short run productivity effects. However, this strand of literature lacks any conclusive causal results.

2.3 Spillover effects

After having described what the effects of direct linkages are, it remains to substantiated how these (productivity or knowledge) spillover occur. The rich FDI literature describes the mechanisms through which these spillovers are transferred. There are three main channels through which firms appear to receive spillovers (Saggi, 2006; Smeets, 2008). First, vertical linkages which describes the spillover of knowledge from the MNE to its suppliers and buyers. Second, demonstration effects where processes or products of the MNE are imitated or reverse-engineered by the domestic firm as to improve their productivity. Third, the mobility of workers from MNEs to domestic firms or vice versa. Examining the vertical linkage channel and the worker mobility through vertical linkages offers insights into the mechanisms into how domestic firms experience spillover effects from supplier or buyer linkage with MNEs.

2.3.1 Vertical linkages

The explosion in papers on vertical linkages was initially inspired by the well-known Javorcik (2004) paper.[12] The paper explores how vertical linkages, specifically backward linkages, benefit domestic firms. Javorcik (2004) argues that vertical linkages transfer from the MNE to the domestic firm in three ways. First, MNE facilitate the transfer of knowledge by providing technical assistance, management training, knowledge on how to organise the production process, helping to expand the network of the domestic firm and provide access to the network of the MNE. Second, MNEs require higher (quality) standards and will put more pressure on domestic firms to deliver products on time with a higher quality. The pressure of the MNE incentivizes domestic firms to invest in their current production facilities as to meet the standards set by the MNE. Thirdly, the increased demand and long-term security MNEs offer, due to the longer-term contract MNEs offer, results in domestic firms being able to reap the benefits of economies of scale. These claims are backed up by more recent literature on the topic. Namely, Alfaro-Ureña et al. (2022) use survey data to further understand the consequentiality of becoming a first-time supplier to a MNE. The domestic suppliers reported a range of changes that arose due to the interaction with MNE. Listed changes include better managerial and organisational practices, expansions in product scope (with higher quality products), and improved reputation. This shows that MNEs exert pressure to force domestic firms to bridge large gaps in productivity. This results in domestic firms being able to lower marginal costs assuring gains for the MNE, while subsequently increasing the competitiveness of the domestic firm.

[12] See Havránek and Iršová (2011) for a meta review of literature during this period and Rodriguez-Clare (1996) for a theoretical model.

2.3.2 Worker mobility through vertical linkages

Supplier or buyer linkages between firms appear to exacerbate worker mobility between firms. In a recent working paper of Cardoza et al. (2023), one-fifth of the job transitions of workers in the Dominican Republic are to a buyers or suppliers of the workers original employer. On average, workers enjoy a 7% premium for moving along the supply chain, two-thirds of which is accounted for by moves to higher wage firms (Cardoza et al., 2023).[13] Also, moving along the supply chain increases the number of sales between firms with buyer or supplier linkages. Komatsua and Dhyne (2023) link Belgian firm linkages with employer-employee data and find that a staggering 42% of job transition are made to suppliers or buyers of the workers original employer. This back-ups the claims of Cardoza et al. (2023) that countries with more robust production network have stronger job market ladders. Production networks are thus likely to facilitate a better match compared to random job searching which possibly enhances productivity gains.

Survey results of Cardoza et al. (2023) suggest that the supply chain earnings premiums arise due to supply chain specific human capital, increased information about the worker and their abilities, and movers being compensated for facilitating an increase in trust between the firms. As MNEs pay higher wages, a fast majority of the moves are possibly from the domestic firms to MNEs which may indicate that the worker mobility channel for spillovers along vertical linkages decreases the productivity spillovers from this channel. However, there remains to be a high level of ambiguity. Moves from buyer to supplier possibly result in a net zero productivity effect, as the improved marginal cost of the supplier results in lower input prices for the buyer, offsetting the loss in productivity of the buyer. Alternatively, moves from suppliers to buyers can result in a productivity loss if the increase in sales to the buyer is not compensating for the loss in productivity of the worker. Therefore, the level of productivity spillovers is depending on the amount of 'random' workers the domestic firm can attract from the MNE, and ambiguously, the amount of workers along the supply a domestic firm can attract or lose.

[13] Wages, arguably, represent the marginal product of labour which implies that wage increase are representative of productivity increases. This claim is reliant on the fact that wage premiums are not due to increases in labour demand. The (causal) literature finds that MNE positively effect of the wages of domestic firms (see Balsvik (2011), Poole (2013), and Setzler and Tintelnot (2021) and for a paper about the Netherlands see Rösch et al. (2024)).

2.4 Hypotheses

After having discussed the relevant literature, the paper proposes the following hypotheses. First, it is expected that the Dutch firm network follows stylized facts 1)-3) of section 2.1.2. Again, this implies that there is a high degree of dispersion in the number of buyers and suppliers, the network follows a Pareto distribution, there is a positive correlation between the number of connections and the size of a firm, and the network exert negative degree assortativity. Second, domestic firm experience productivity gains from being connected to a MNE. Suppliers potentially benefit from the worker mobility and the effects of vertical linkages. Buyers of MNEs likely experience the effects of vertical linkages to a lesser extent compared to suppliers of MNEs as the cost structure of the MNE depends on the choice of suppliers. Thus, it is expected that suppliers of MNEs to benefit more due to the nature of these relations. MNE may compete with domestic firms by 'stealing' the business of the domestic firm (Bloom et al., 2013). The question remains whether potential spillovers are able to compensate for competition effects and negative effect of worker mobility competition.

3 Data and descriptive statistics

This section aims to provide insight into the main data sources and descriptive statistics for the domestic companies within this dataset. Statistic Netherlands developed a method to artificially reconstruct the Dutch business production network by leveraging firm characteristics from administrative data. Dutch firms have no legal obligation to report their linkages, unlike some other countries, where firms provide this information as part of their VAT declarations. It is important to note that this data only captures intermediary transactions between firms. This implies that consumer interactions and transactions between the Dutch firms and firms from other countries are not considered. The matching process relies on literature based scores relying on a company score, a distance score and an industry score. It is assumed that extrapolation represents reality. The method is constructed using an iterative proportional fitting as to assure consistency compared to a machine learning based approach as in Mungo et al. (2023). Appendix A provides a breakdown of the crucial parts of the reconstruction method relevant for this study.

The main data set captures roughly 900.000 firms annually with a minimum turnover of 10.000 euro or more. Note that, approximately 800.000 'micro-firms' are excluded from the estimation due to this minimum. These firms are mainly self-employed persons and their combined turnover is 0.5% of GDP in the Dutch economy. The weights of these transactions are distributed over all other firms which results in a slight overestimation. These weights

are constructed as to be consistent with the input-output tables of the Dutch economy. The transactions are classified into the most detailed commodity grouping available to CBS which is the '650-level'. The Algorithm mistakenly creates matches of firms that supply themselves. These transactions are removed in all samples. Some transactions have a zero weight, the zero weights appear when the industries do not trade with one another according to the input-output table. It is assumed that these are mistakes of the algorithm resulting a removal in all samples. Table 1 shows basic summary statistics of the network for each year. The resulting network in total has 17.987.460 observations with 1.029.24 unique suppliers and 1.093.949 unique users. It has to be noted that, the amount of observations from 2018 to 2019 and 2020 significantly drops. This is due to a bug in the algorithm and the new version of the network will not have this issue.[14] The models solve for this by adding year fixed effects.

	Mean	SD	Min	Max	Count
2018					
Number of supplier linkages	10908.724	43787.628	1	249090	8524973
Number of buyer linkages	48.354	55.685	1	651	8524973
2019					
Number of supplier linkages	15487.086	51340.152	1	238302	5106463
Number of buyer linkages	37.206	52.629	1	599	5106463
2020					
Number of supplier linkages	14339.090	46278.409	1	211195	4356024
Number of buyer linkages	34.664	47.956	1	520	4356024
Total					
Number of supplier linkages	13039.208	46689.475	1	249090	17987460
Number of buyer linkages	41.874	53.400	1	651	17987460

Table 1: Summary statistics yearly network characteristics

Appendix B shows that the Dutch network follows stylized facts 1-3 of section 2.1. To reiterate, this implies that there is a high degree of dispersion in the number of buyers and suppliers, the network follows a Pareto distribution, there is a positive correlation between the number of connections and the size of a firm, and the network exerts negative degree assortativity. This increases the confidence in the ability for the algorithm to, on average,

[14]This paper used the version prior to the newly released datasets of August 2024. The new version was not available at the time of running the results.

accurately predict the network of domestic firms.

The business network data is merged with productivity data, and with a set of rich firm characteristics over the time period 2018-2020. The productivity data is partially extrapolated in order to estimate the productivity of firms that are under no obligation to report all required statistics. The exact methods of this imputation are to me unknown and further details remain to be provided by Statistics Netherlands. The firm characteristics are taken from the Algemene Bedrijven Register and import and export registers. The imputation of the business network is partially based on observed data thus this will be used to check the consistency of the findings. The observed linkage data is from Dun & Bradstreet (DAB) which contains links of large Dutch firms with their respective suppliers and buyers. The network characteristics hold using the DAB data which can be seen in Appendix B. The DAB data is not suited to recreate the results as the DAB data primarily observes large firms very few of which are domestic suppliers. There is an insufficient amount of observations to run any of the models using the DAB data.

	mean	sd	min	max	count
TFP (ACF)	33851.122	36611.724	41	3276408	141466
weight in tfp (ACF): labour	0.877	0.058	0	1	141466
weight in tfp (ACF): capital	0.101	0.037	0	0	141466
TFP Productivity Growth method	25177.322	160709.888	1	28598460	141466
weight in tfp (growth accounts): labour	0.841	0.088	0	1	141466
weight in tfp (growth accounts): capital	0.159	0.088	0	1	141466
Labour productivity (value added per worker)	84548.887	112843.745	96	26345212	141466
Number of linkages buying from Domestic firms	25.886	25.423	0	334	141466
Number of linkages buying from Domestic MNEs	0.269	0.653	0	13	141466
Number of linkages buying from Foreign MNEs	3.287	4.003	0	89	141466
Number of linkages supplying to Domestic firms	17.361	206.759	0	54411	141466
Number of linkages supplying to Domestic MNEs	0.083	0.748	0	109	141466
Number of linkages supplying to Foreign MNEs	0.711	5.068	0	700	141466
Number of linkages supplying to Brexit firms	0.911	4.098	0	343	141466
Number of linkages buying from Brexit firms	1.875	2.177	0	26	141466
Size Classification	35.231	12.427	21	93	141466
Firm imports	183304.959	5276613.740	0	1.83e+09	141466
Firm exports	207949.196	2693522.697	0	424182688	141466
employees, fte (includes corporate owner(s))	18.525	84.370	2	12297	141466
capital, 2015-prices, 1000 euro	1224158.682	20118024.377	1	4.97e+09	141466

Table 2: Summary statistics domestic firms

Table 2 shows summary statistics of all domestic firms in the sample. The sample has a total of 53.206 unique domestic firms over the period of 2018 to 2020 which results in 141.466 observations. Domestic firms have on average 26 connections as users to other domestic firms and 17 as suppliers to other domestic firms. This is significantly different compared to their other interactions which the average firm does not even have one of. To note, one can observe

that the size class has a minimum of 21 which implies that smaller firms (employees at less then 2 FTEs) are not accounted for in this sample.

The main dependent variable of this study is the productivity of a domestic firm. Productivity is often measured in the literature using total factor productivity (TFP) (Havránek & Iršová, 2011) and primarily calculated by using the OLS-, Olley and Pakes (1996) (OP)- or Levinsohn and Petrin (2003) (LP) method. Primarily, these methods are making use of firm level data such as labour, capital, value added, intermediate inputs and investments in order to calculate the subsequent output elasticities of the respective inputs. Each method aims to solve an econometric issue that arose in earlier estimation methods. The main improvement of the LP being that it decreases the data requirements of the OP method by using intermediate inputs instead of investments, while still solving the simultaneity problem that may arise when using labour productivity for example. Additionally, it is believed to decrease the endogeneity of the labour inputs. However, Ackerberg et al. (2015) argue that the underlying issue is the collinearity between a firms input and the productivity levels. Therefore, when unobserved productivity shocks occur endogeneity is introduced for which the other method do not account. Ackerberg et al. (2015) (ACF) estimation method accounts for this endogeneity and is therefore this method of estimating total factor productivity is believed to yield a more accurate measure. In the robustness checks, alternative estimations for productivity like labour productivity or the production growth method of calculating TFP are shown. Please refer to appendix C to find additional information on the calculations of the TFP.

4 Methodology

The base line empirical strategy aims to capture the correlation between the productivity of a domestic firm and a change in the supplier of buyer network of the firm. The models show an OLS estimation with log first-differences to capture a change in linkages and productivity for each firm i in year $t \in T$ of time period $T = \{2018, 2019, 2020\}$.

$$\Delta \ln(y_{it}) = \beta_0 + \beta_1 \sum_{j \in J} \Delta \ln(F_{itj}) + \beta_2 \sum_{j \in J} \Delta \ln(B_{itj}) + \beta_3 \Delta \ln(X_{it}) + \lambda_{spt} + \alpha_i + \epsilon_{it} \quad (1)$$

Where y_{it} is an outcome variable such as TFP, β_0 is the constant. $F_{it} := \sum_{k=1}^{K} \mathbb{1}_{kt} e_{itk} \omega_{itk}, \forall i \in V, \forall t \in T$ of graph $G_t(V, E)$ where $K \in E$ represents the total number of edges firm $i \in V$ has. $\mathbb{1}_{itkj}$ is an indicator function of whether the edge is equal to a specific firm type $j \in J$ where $J = \{$Domestic firm, Domestic MNE, Foreign MNE$\}$ to which the firm supplies. e_{itk}

rotates through all the edges of firm i with weight ω_{itk} of each transaction.[15] Therefore, F_{it} captures the total number of firm type linkage J firm i supplies in year t also known as the outdegree in graph theory terminology. Idem for B_{it}, as this variable captures the total number of linkages firm i is being supplied by in year t, which is known as the indegree. This allows me to break down the coefficients of different types of linkages.[16] X_{it} is a vector of firm level control variables which include firm size, import and export of a firm. λ_{spt} captures sector $\times$ region $\times$ year fixed effects, α_i are firm fixed effects and ϵ_{it} is an error term. The models use robust- and clustered standard errors at two-digit sector $\times$ region level as in Alfaro-Ureña et al. (2022). The productivity of firms within the same sector and region are likely to show serial correlation of errors, thereby clustering at the sector $\times$ region level results in more in restrictive standard errors compared to firm level clustering. To note, $\ln(1+x)$ is used to for all variables but the dependent variable as all variables are not normally distributed. This slightly changes the interpretation, especially if the input variables have large values. However, most of the variables have small input values. Therefore, I assume that $\ln(1+x)$ approximates percentage changes ($\ln(x)$).

This model captures the essence of the previous literature that aims to proxy forward- and backward linkages (Havránek & Iršová, 2011) but at a more dis-aggregated level. The identifying assumption relies on the fact that the gain or loss of a connections is exogenous with respect to the error term. This would imply that the change in linkages is not influenced by unobserved factors that also affect the productivity change of the firm. This assumption is violated if the fixed effects or control variables do not capture all unobserved shocks, resulting in omitted variable bias, or issues with reverse causality. Reverse causality would occur when changes in the firm's productivity result in changes in the amount of linkages, rather than the other way around. This would bias the estimation.

A shock to the network is leveraged due to MNEs that came due to the Brexit in an attempt to account for the endogeneity of equation (1). This shock attempts to account for the reverse causality issues. Brexit firms are defined as firms that changed ultimate ownership status from the United Kingdom to the Netherlands. The total amount of the joining Brexit firms is 146 firms compared to 584 leaving Brexit firms (firms that changed ultimate ownership status from the Netherlands to UK). It is important to note that, prior to the change by definition these joining Brexit firms were classified as foreign MNEs as these firms already had a subsidiary in the Netherlands. Moreover, Brexit joining firms

[15] $e_{itk} = 1, \forall i, t, k$ as each transaction is unique and multiple transaction are aggregated into one edge. $\omega_{itk} = 1, \forall i, t, k$ if not specified as weighted. The weight represents the aggregated transaction size in 1000 of euro's.

[16] Appendix C visually show how F_{it} and B_{it} are calculated.

that did not have any prior entity in the Netherlands are not counted as Brexit firms. The switch in ownership status is not observed which lingers identification. New linkages that the Brexit firms create are likely not due to the change in productivity of the domestic firm. Brexit firm need to acquire linkages in order to be supplied or find new buyers as a consequence of changing their operations. Thus, Brexit resulted in a major economic shift as many firms from the United Kingdom started looking for ways to continue their operations in the European Union, therefore a move to the Netherlands is likely strategic in its nature. The results of table 6 in appendix D, shows a regression with the lagged productivity of domestic firm and the number of linkages in the current period. Reassuringly, it shows that the productivity of the prior period is not correlated with the amount of Brexit suppliers of a domestic firm. The amount of non-Brexit connections does appear to correlate to the lagged productivity of the domestic firm. Therefore, the use of Brexit variation potentially results in variation such that the reverse causality concerns are arguably alleviated. Table 7 in appendix D shows, a regression of the number of connections and a dummy whether the firm changed ownership status. Firms that change the ultimate owners from the United Kingdom to the Netherlands significantly increased their supplier networks. Surprisingly, firms that changed ultimate owner from the Netherlands to the United Kingdom (leavers) also appeared to have increased the number of connections in the Netherlands. The Brexit shock appears to not be monotonic which is major point of concerns for identification.

A propensity score matching strategy offers a strategy to control for the non-monotonic shock resulting from these Brexit 'leaver' firms. This control strategy is constructed by predicting the chance of being affected by Brexit leaver supplying connection based on firm size, region, sector, imports and export using a probit regression. The resulting predicted probabilities (p-scores) are used to match firms that were not affected by Brexit leaver supply connection to those that were affected. The differences between these p-scores must not be larger than 0.01 (also referred to as the caliper) which ensures strong matches. Appendix D delves deeper into the quality of the matches. The result of these tables affirm the adequacy of the resulting matches and increase the confidence in ability for non-Brexit leaver to form a credible counterfactual group. The matching occurs based on the k-nearest neighbours method which requires a trade-off between the amount of bias reduction and variance. The estimates are compared using 1, 3, 5, and 10 neighbours as to assure a balanced trade-off is found. The usage of propensity score matching allows for a correction resulting from the lack of a monotonic relation resulting from the Brexit variation.

First-time suppliers potentially experience obtaining a new foreign MNE supplier connection differently compared to firms that were already connected to foreign MNEs, as

described in Alfaro-Ureña et al. (2022). This motivates the addition of a first time Brexit supplier dummy. The resulting regression equation is set-up as follows:

$$\Delta \ln y'_{it} = \beta_0 + \beta_1 \Delta \ln F_{it} + \beta_2 \Delta BS_{it} + \beta_3 \Delta \ln B_{it} + \beta_4 \Delta \ln X_{it} + \lambda_{spt} + \alpha_i + \epsilon_{it} \quad (2)$$

y'_{it} represents the dependent variable TFP corrected for the Brexit leavers using the propensity score matching. F_{it} captures the amount of supplier linkage with entering Brexit firms. BS_{it} is a dummy variable whether the firm is a first-time supplier to a Brexit firm. B_{it} is the amount of Brexit linkages which supply the domestic firms. To note, these Brexit firms are all former foreign subsidiaries that changed to being a domestic firms or a domestic MNE. Therefore, it does not make sense to split the linkages into the different types of linkages J.

The identifying assumption of the propensity score matching strategy relies on the fact that non-Brexit leaver affected firms form a credible counterfactual group to the firms that were affected by Brexit leaver supply connections. The conditional independence assumption states that the outcome must be independent of the treatment status given the covariates, expressed as $(y_1, y_0) \perp T|X$. Therefore, it is assumed that firms affected by Brexit leavers firms are chosen based on the matching variables and that all remaining variation is independent of the the treatment status. Next, this strategy assumes that every treated unit matched with a high quality counterpart in the control group. It can be accessed from appendix D that, except when using 10 neighbours in some cases, all treated units have a high quality match with a non-treated counterpart. Last, the potential outcome of one unit cannot be predicted by the outcome of another unit. The treatment of one firm cannot predict the treatment of another firm. The data is analysed on business unit level and the linkages are also determined on this level. Therefore, it seems unlikely that the treatment of one business units determines the treatment of another business unit.

The endogeneity from the reverse causality is plausibly eliminated due to the usage of Brexit variation. However, the omitted variable bias likely remains a problem as a connection with a Brexit firm is potentially different to a connection with other foreign MNEs. Table 8 of appendix D explores some descriptive statistics of the Brexit firms compared to other foreign MNEs. It shows that Brexit firms are not significantly more productive compared to other foreign MNEs but they do appear to be significantly larger in size. A further discuss the limitations of this model is provided in the limitations section.

5 Results

5.1 Linkages and domestic firm productivity

Table 3 shows the results of the OLS regression of equation (1) that estimates the productivity of a domestic firm and the development of its network. Column 1 shows estimates with less restrictive fixed effects, including sector, year and region FE. Column 2 adds firm fixed effects. Firm fixed effects reduce potential omitted variable bias by controlling for time invariant firm level characteristics. The estimate of column 1 indicate that network growth with either buyers or suppliers is, on average, positively correlated with the productivity of the domestic firms. A one percent increase in the number of linkages where the domestic firm buys from another domestic firm is associated with an average increase between 2.80% and 0.92% in the productivity of the domestic firm and 0.46%, 0.22% for domestic MNEs and foreign MNEs, respectively. Growing the number of linkages where the domestic is the supplier in the network appears to be positively correlated with the productivity of the domestic firm. While the statistical significance differs between the models, increasing the number of supplying connections with domestic firms by one percent is, on average, associated with a 0.08% increase in the productivity of the domestic firm and 0.21%, 0.18% for domestic MNEs and foreign MNEs, respectively. The significance level of different types of linkages differs between the models as increasing the size of the number of firms the domestic firm buys from domestic MNEs in model 2 is not statistically different from zero. Similarly, increasing the size of the supplying connections to domestic MNE or foreign MNE is not statistically significant from zero in model 2. When interpreting these estimates one has to keep in mind that the average network size of domestic firms with domestic linkages is larger than the average network size of the domestic firm with foreign MNEs which indicates that one percent change can differ strongly in absolute terms.

Column 3 and 4 shows difference equation (1) with column 3 adding sector, region and year fixed effects. Column 4 again adds firm fixed effects. The estimates indicate that a change in the number of domestic firms or foreign MNEs the domestic firm buys from is associated with an increase of productivity of the domestic firm. A change of one percent in the number of linkages the domestic firm buys from is, on average, associated with a productivity increase ranging from 0.91% to 1.0% and 0.12% to 0.16% for domestic firm buying linkages and foreign MNEs buying linkages, respectively. A change in linkages between domestic MNE buying linkages, nor any type of supplying linkage does not appear to correlate with the productivity of the domestic firm. While, column 2 and 4 add more restrictive firm fixed effects it might be the case that this overestimates the model keeping in mind that the

panel only spans three years. A negative R-squared can be an indication for overestimation which is the case in model 4. Therefore, it must be questioned if the firm fixed effects are too restrictive in model 4.

	OLS		Δ OLS	
	(1)	(2)	(3)	(4)
	ln TFP ACF	ln TFP ACF	Δ ln TFP ACF	Δ ln TFP ACF
ln Number of linkages buying from Domestic firms	0.281***	0.0921***	0.0913***	0.100***
	(0.00684)	(0.00678)	(0.00522)	(0.0106)
ln Number of linkages buying from Domestic MNEs	0.0464***	0.00134	-0.00679	-0.0159
	(0.00597)	(0.00709)	(0.00548)	(0.0130)
ln Number of linkages buying from Foreign MNEs	0.0222***	0.0102**	0.0115***	0.0160**
	(0.00439)	(0.00514)	(0.00410)	(0.00746)
ln Number of linkages supplying to Domestic firms	0.00399	0.00813**	0.00423	0.00356
	(0.00386)	(0.00370)	(0.00311)	(0.00589)
ln Number of linkages supplying to Domestic MNEs	0.0207**	0.00785	0.00986	0.00648
	(0.00901)	(0.0103)	(0.00784)	(0.0151)
ln Number of linkages supplying to Foreign MNEs	0.0177***	0.00463	0.00124	-0.00325
	(0.00419)	(0.00413)	(0.00339)	(0.00614)
Size Classification	-0.0139***	-0.00431***	-0.00293***	-0.00136
	(0.000375)	(0.000598)	(0.000491)	(0.000994)
ln Imports	0.00189***	-0.000762	-0.000420	-0.000319
	(0.000538)	(0.000514)	(0.000416)	(0.000879)
ln Exports	0.00751***	0.000997	0.00112**	0.000466
	(0.000727)	(0.000685)	(0.000546)	(0.00103)
Constant	9.771***	10.01***	-0.0246***	-0.0218***
	(0.0119)	(0.0310)	(0.00192)	(0.00414)
Observations	141466	127244	78560	63418
R-squared	0.506	0.893	0.150	0.512
Adjusted R-squared	0.471	0.807	0.0829	-0.152
Firm FE	No	Yes	No	Yes
Sector#Region#Year	Yes	Yes	Yes	Yes

Table 3: The productivity of domestic firms and its linkages

Notes: This table shows the results of an OLS regression of equation 1 where the F_{it} is represented by the linkages as supplier (outdegree) and B_{it} by the linkages as buyer (indegree). Region, year, and 2 digit sector code FE are used if Firm FE is not used. Standard errors in parentheses. Clustering of standard errors at 2 digit sector and region level. ***,**,* denote α at the 1%, 5%, and 10%, respectively.

Table 8 and 9 in appendix D explore the robustness of these results to changing the productivity measure. The main results appear to relatively robust with respect to the estimation method and productivity measure constraints.

5.2 Dependency on linkages

This part explores how increasing the dependency on linkages with certain types of connection is correlated with the productivity of domestic firms. F_{it} and B_{it} are recalculated using the sum of the weights (transaction values in 1000 euro's) and normalised by the sales of the firm. A normalisation to the variable is applied as to assure comparability across firms. This results in the normalised weighted outdegree or F'_{it}. Idem for B'_{it}.

$$F'_{it} = \frac{F_{it}}{\text{Sales}_{it}} = \frac{\sum_{k=1}^{K} \mathbb{1}_{kt} e_{itk} \omega_{itk}}{\text{Sales}_{it}}, \omega_{itk} \in (0, \infty)^{17}$$

Table 4 shows the correlation between the productivity of a domestic firm and the summed normalised weight of the transactions for each type of connection. The results indicate that increasing the dependency on domestic firms for buyer and supplier transactions is negatively correlated with productivity while increasingly the dependency on foreign MNEs is positively correlated with the productivity of domestic firms. A one percent increase in the weighted transactions to domestic firms, on average, is associated with a decrease in productivity ranging from 0.80% to 0.25% for buying transactions and 1.28% to 0.38% for linkages where the domestic firm supplies another domestic firm. The difference equations of column 3 and 4 estimate coefficient ranging from -0.22% to -0.14% and -0.33% to -0.23% for buying- and supplying relations, respectively.

On the contrast, increasing the dependency on linkages with foreign MNEs appears to positively correlate with the productivity domestic firms. The estimates range from 0.63% to 0.16% for a one percent increase in the weighted buying transactions from foreign MNEs and 0.81% to 0.11% for supplying transactions to foreign MNEs. The difference equation produces similar results to the firm fixed effects equation being 0.13% for buying linkages and 0.09% for supplying linkages. Again, the results of model 4 might be overestimated, indicated by the negative adjusted R-squared.

Tables 23 and 24 of appendix E show the estimates using alternative productivity measures. The results are robust to changing the productivity measure.

Domestic firms, compared to foreign MNEs, are less innovative, have more limited market access, have lower quality standards, and likely have less competitive pressure as described in the literature review. Thereby, it is likely that linkages with these firm are more transactional in nature which is possibly explained by the positive estimates from increased in the absolute number of linkages. The relative measure likely controls for the transactional nature by normalising the weight to each group. These estimates lead me to conclude that domestic

[17] Note that, all 0 weights are removed. Therefore, $\omega_{itk} \neq 0 \ \forall i \in V$.

firms benefit from increases in demand or supply from an increase in suppliers or buyers. However, the relative transaction size resulting from increasing the dependency on foreign MNEs is positively correlated with the productivity of the domestic firm compared to a negative correlation with increasingly the dependency on domestic firms.

	OLS		Δ OLS	
	(1)	(2)	(3)	(4)
	ln TFP ACF	ln TFP ACF	Δ ln TFP ACF	Δ ln TFP ACF
ln Normalised weighted linkages buying from Domestic firm	-0.0799***	-0.0247***	-0.0219***	-0.0136***
	(0.00299)	(0.00300)	(0.00219)	(0.00400)
ln Normalised weighted linkages buying from Domestic MNE linkages	0.00660	0.0129**	0.0136***	0.0159
	(0.00641)	(0.00649)	(0.00514)	(0.0109)
ln Normalised weighted linkages buying from Foreign MNE linkages	0.0628***	0.0163***	0.0134***	0.0000886
	(0.00424)	(0.00468)	(0.00360)	(0.00769)
ln Normalised weighted linkages supplying to Domestic firm linkages	-0.128***	-0.0382***	-0.0334***	-0.0231***
	(0.00271)	(0.00265)	(0.00197)	(0.00340)
ln Normalised weighted linkages supplying to Domestic MNE linkages	0.0501***	0.0215	0.0306**	0.0374*
	(0.0177)	(0.0160)	(0.0125)	(0.0203)
ln Normalised weighted linkages supplying to Foreign linkages	0.0813***	0.0110*	0.00873*	0.00581
	(0.00542)	(0.00617)	(0.00469)	(0.00773)
Size Classification	-0.00576***	-0.00347***	-0.00236***	-0.00131
	(0.000208)	(0.000615)	(0.000497)	(0.000999)
ln Imports	0.00578***	-0.000715	-0.000444	-0.000307
	(0.000548)	(0.000516)	(0.000408)	(0.000886)
ln Exports	0.00503***	0.000987	0.00113**	0.000394
	(0.000736)	(0.000702)	(0.000555)	(0.00104)
Constant	10.48***	10.33***	-0.0576***	-0.0569***
	(0.00854)	(0.0222)	(0.000858)	(0.00177)
Observations	138761	124139	76501	61550
R-squared	0.489	0.893	0.157	0.511
Adjusted R-squared	0.452	0.807	0.0899	-0.158
Firm FE	No	Yes	No	Yes
Sector#Region#Year	Yes	Yes	Yes	Yes

Table 4: The productivity of domestic firms and weight of linkages

Notes: This table shows the results of an OLS regression equation 1 where F'_{it} and B'_{it} is used. Region, year, and 2 digit sector code FE are used if Firm FE is not used. Standard errors in parentheses. Clustering of standard errors at 2 digit sector and region level. ***,**,* denote α at the 1%, 5%, and 10%, respectively.

5.3 Brexit linkages and the productivity of domestic firms

Table 5 shows the estimates of equation (2) with a base OLS in column 1 and 2 to act as comparison for the difference equation in column 3 and 4. The amount of neighbours determines the bias to variance trade-off. A low amount of neighbours creates a lower bias but increases the variance, more neighbours stabilises the variance. The non-significance of the results in models using 1 neighbour might be resulting from the increase in variance of

the matching procedure. In appendix D, it was concluded that the matching quality only decreases when using 10 neighbours. Therefore, models with 3 and 5 neighbours appear to be adequately balanced in terms of bias reduction and variance stabilisation.

Analysing the results of column 1 and 2 show that domestic firms that form connections as suppliers with Brexit firms appear to benefit from these interactions. A one percent increase in the number of linkages supplying to Brexit firms is, on average, associated with an increase in the productivity of the domestic firm ranging from 0.072% to 0.124%.

The difference equation estimates remarkably similar coefficients. A one percent change in the number of linkages as supplier to Brexit firms is associated with an increase of 0.12% to 0.13% in the productivity of the domestic firm. The results of the buyer relations, where the domestic firm buys from the Brexit firm is not significant in any estimation.

Domestic firms that supply a Brexit firm, while never having supplied a Brexit firm before, have lower productivity gains compared to domestic firm who are not first-time Brexit suppliers. This seems contrary with the results of Alfaro-Ureña et al. (2022) as they show a persistent positive TFP effect directly after the event of a first-time MNE supplier supplying a foreign MNE. However, the models do predict strong productivity gains as the average network size with these Brexit firms is low as, on average, firms only have one Brexit firm they supply. Firms that go from 0 to 1 Brexit suppliers are predicted to gain 0.90% to 0.81% in TFP. When a firm is a first-time Brexit supplier they are expected to lose 1.2 to 0.86% of this expected gain. This results in a net loss of -0.3 to -0.05% in the first year of being a first time Brexit supplier. After the subsequent transitory first year supplier year, the domestic firm is expected to gain productivity.

Marginal cost curves are likely to be upward sloping in the short run after a domestic firm becomes a first-time supplier to a foreign MNE. Alfaro-Ureña et al. (2022) provide a descriptive model of the dynamics of the marginal cost curves. They provide estimates and show large and negative marginal costs in the short-run and they estimate that these marginal costs of supplying the MNE approach zero over time. These first-timers arguably show these large negative short-run effects and the overall positive effects of these linkages show the medium- to long-run marginal costs of supply the MNE approaching zero. Alfaro-Ureña et al. (2022) argue that firms cannot immediately adjust fixed factors such as capital and increase flexible inputs such as labour resulting in capacity constraints, lowering the amount of sales to others directly after the event. Therefore, the estimates likely do not show the full extent of the expected positive effect as the models observe a maximum of 2 years after the change in linkages.

	OLS		Δ OLS	
	(1)	(2)	(3)	(4)
	ln TFP ACF	ln TFP ACF	Δ ln TFP ACF	Δ ln TFP ACF
Panel A: 1 neighbour				
ln Number of linkages buying from Brexit firms	0.0015	0.0015	-0.0001	-0.0034
	(0.0072)	(0.0072)	(0.0058)	(0.0110)
ln Number of linkages supplying to Brexit firms	0.0034	0.0038	0.0046	-0.0065
	(0.0069)	(0.0087)	(0.0072)	(0.0175)
c First time supplying a Brexit firm	.	-0.0009	-0.0046	0.0055
		(0.0090)	(0.0074)	(0.0160)
Adjusted R-squared	0.4867	0.4867	0.1728	-0.2463
Panel B: 3 neighbours				
ln Number of linkages buying from Brexit firms	0.0023	0.0022	0.0011	-0.0005
	(0.0045)	(0.0045)	(0.0037)	(0.0070)
ln Number of linkages supplying to Brexit firms	0.0072*	0.0124**	0.0131***	0.0128
	(0.0042)	(0.0054)	(0.0046)	(0.0123)
First time supplying a Brexit firm	.	-0.0119**	-0.0127***	-0.0090
		(0.0058)	(0.0047)	(0.0105)
Adjusted R-squared	0.5665	0.5665	0.0951	-0.2407
Panel C: 5 neighbours				
ln Number of linkages buying from Brexit firms	0.0014	0.0014	-0.0005	-0.0051
	(0.0037)	(0.0037)	(0.0030)	(0.0057)
ln Number of linkages supplying to Brexit firms	0.0073**	0.0113**	0.0117***	0.0131
	(0.0035)	(0.0044)	(0.0037)	(0.0093)
First time supplying a Brexit firm	.	-0.0090*	-0.0087**	-0.0080
		(0.0048)	(0.0039)	(0.0083)
Adjusted R-squared	0.6144	0.6145	0.0930	-0.2327
Panel D: 10 neighbours				
ln Number of linkages buying from Brexit firms	0.0012	0.0011	-0.0011	-0.0044
	(0.0028)	(0.0028)	(0.0023)	(0.0043)
ln Number of linkages supplying to Brexit firms	0.0051*	0.0066**	0.0080***	0.0111
	(0.0027)	(0.0032)	(0.0028)	(0.0070)
First time supplying a Brexit firm	.	-0.0033	-0.0044	-0.0066
		(0.0036)	(0.0031)	(0.0066)
Adjusted R-squared	0.6667	0.6667	0.0818	-0.2408
Observations	86,988	86,988	54,551	45,838
Firm FE	Yes	Yes	No	Yes
Sector#Region#Year	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

Table 5: The productivity of domestic firms with propensity score matching and Brexit linkage variation

Notes: This table shows an OLS regression with propensity score matching. Controls include firm size, imports, exports. Furthermore, region, year, and 2 digit sector code FE are used if Firm FE is not used. Standard errors in parentheses. Clustering of standard errors at 2 digit sector and region level. ***,**,* denote α at the 1%, 5%, and 10%, respectively.

Table 25 in appendix E breaks down TFP into its components labour and capital. A change in the number of supplying linkages with Brexit firms does not appear to increase

the amount of labour used. However, a domestic firm that supplies a Brexit firm for the first time is predicted to use more labour compared to firms that are not firm-time Brexit suppliers. Capital is not significantly different from zero after a change in the number of supplying linkages with Brexit firm being first-time supplier or not. This suggests that firms increase more flexible inputs such as labour and are not able to change fixed inputs such as capital.

Table 26 of appendix E shows a placebo test. This method checks for spurious correlation by changing the independent variables of interest to random integers. The results indicate that the estimation are not due to randomness as the coefficients are all insignificant. Therefore, the estimation are robust to spurious correlation.

Tables 27 and 28 of appendix E shows the estimates using alternative productivity measures. The results are not robust to both of these alternative productivity estimations. Ackerberg et al. (2015) method of constructing TFP controls for the correlation between inputs and any unobservable productivity shocks, refer to appendix D for more details. The inability of the other methods to control for these biases results in insignificant results. These estimates suggest that controlling for endogeneity of the inputs, used when constructing TFP, is essential for obtaining consistent results.

In alignment with Alfaro-Ureña et al. (2022), the estimates predict that domestic firms gain productivity when engaging in supplier connections with MNEs. Masso and Vahter (2023) suggest that the TFP effects take time to materialize which is suggested by lack of significance of difference equation (1). However, the authors calculate TFP using Levinsohn and Petrin (2003) and GMM method which fails to control for the simultaneity between inputs and productivity shocks compared to Ackerberg et al. (2015)'s method. This aligns with the earlier estimations in tables 26 and 27 of appendix E which uses TFP methods that also fail to control for the simultaneity issue. Therefore, it is likely that the effects on TFP materialize in a shorter time frame then Masso and Vahter (2023) estimated. Furthermore, as anticipated in the literature review, first-time Brexit suppliers indeed appear to face short-run capacity constraints resulting in a temporary reduction in productivity. The estimates are not conclusive about the source of this temporary reduction. Productivity gains from being a buyer to a MNE still remains ambiguous as the estimates fail to find significance using equation (2) while documenting significant findings from equation (1). Overall, these findings increase the confidence in the usage of extrapolated firm-to-firm transaction data to, on average, represent reality. Also, the findings suggest the positive impact of supplier connection with MNEs on the productivity of domestic firms.

6 Limitations

One should interpret these estimates with caution as there are several reasons for concern. First, these estimates are based on a partially extrapolated network and production statistics. The paper assumes that this extrapolation, on average, reflects reality. This is back-up by the data showing all characteristics of the available literature. However, this remains a strong assumption. Second, the dataset spans 3 years which limits the amount of variation observed and the estimates may change when using a longer panel. The dataset likely does not capture the full extend of the long-run effects. It is implicitly assumed that first-time suppliers to Brexit firms experience similar levels of productivity increases compared to non-first time suppliers to Brexit firms after the initial transitory effects of being a first time supplier. This is due the short span of the dataset. However, first-time suppliers possibly experience larger productivity increases after the transitory period compared to non-first time suppliers. Also, the restrictiveness of the fixed effects may have caused insignificant results as large amount of variation is captured. Thus, the results of this study must be replicated using non-extrapolated data with a longer panel to assure full robustness. The ideal candidate is the Belgian data of Dhyne et al. (2022) as the Belgian economy is arguably most similar to the Dutch economy.

Identification lingers on assumptions which are plausibly violated. First, the fact that the Brexit resulted in firms switching firm status from the United Kingdom and vice versa is a concern. These 'leavers' also formed new connections in their Dutch network. Therefore, it is likely that sampled firms were effected by acquiring or losing a linkage with these firms. The propensity score matching model attempts to correct for these leavers, but this model must be interpreted with caution as this method has strong assumptions. Second, the models assume that all labour market effects are captured in the sector region year fixed effects. A violation of these assumptions results in omitted variables. Furthermore, it is assumed that all firms that changed ultimate owners from the United Kingdom to the Netherlands during this period did so due to the Brexit. The usage of this Brexit variation is likely not the most clean identification strategy, however, the use of this variation arguably solves the reverse causality issue offering an improved insight into the nature of linkages with foreign MNEs impacting the productivity of domestic firms.

Similar to Alfaro-Ureña et al. (2022), the data does not allow for a separation of the contribution of the several types of connections to variables related to productivity such as management changes, quality changes, product scopes, and reputation changes. This would require a more rich dataset and arguably a controlled empirical environment (Alfaro-Ureña et al., 2022). Moreover, Alfaro-Ureña et al. (2022) suggest that an increase in mark-ups of the

domestic firms after obtaining a supplier linkage possibly results in increased productivity. The data does not observe product characteristics which does not allow for a exclusion of the effects on mark-up. This is a possible avenue for future research.

7 Conclusion

This paper estimated the productivity effect of domestic firms arising from supplier and buyer linkages with domestic firms, domestic multinationals, and foreign MNEs. The provided data from Statistics Netherlands consists of an economy-wide network dataset of intermediate supplier and buyer linkages along with production statistics, firm characteristics and ownership information of a large set of 53.206 domestic firms in the Netherlands over the period of 2018-2020 resulting in 141.466 observations. The extrapolated firm network data follows the stylized facts found in previous literature that uses non-extrapolated network data.

The main model solves reverse causality issues by using a shock in the network caused by firms that changed ultimate owner from the United Kingdom to the Netherlands due to the Brexit. The non-monotonic nature of the Brexit shock gave use to a propensity score matching model.

The main results show that the productivity of domestic firms is positively affected by linkages with foreign MNEs. Specifically, linkages were the domestic firm supplies a foreign MNEs appear to be beneficial as the results on linkages as buyer appear ambiguous. Similar to Alfaro-Ureña et al. (2022), the results indicate a transitory short-run negative effect on the productivity of a domestic firm after they supply a MNE for the first time. The precise source of the transitory negative effect was not able to be determined. The results are sensitive to the type of productivity measure. Methods that do not control for the endogeneity due to the simultaneity of inputs gave in insignificant results, which may offer insight into why Masso and Vahter (2023) fail to find direct effects on TFP. Overall, these estimates increase the confidence in spillover effects from foreign MNEs to domestic suppliers as found in previous literature.

These results shed a unique light on what it implies for domestic firms to have linkages with different types of firms. Studies in the past are not able to estimate the full extend of direct linkage impacting the productivity of domestic firms. The increasing prevalence of global value chains and the generous tax breaks given to multinationals by policy makers implies a need for a better understanding of the consequentially of multinationals to an economy. Supply chain linkages are one of several effects that foreign direct investment have,

and modelling the role of these linkage results in a better understanding of the complete effect resulting a more efficient usage of tax payer money and a better comparison of all available policy options for policy makers. Motivating the need for more research.

Future research on this topic is likely a fruitful exercise. Recreating the results of this study using non-extrapolated data is invaluable as a confirmation or disproving these results can further point towards the quality of the extrapolation. Furthermore, following the study of Cardoza et al. (2023) and Komatsua and Dhyne (2023), one may further investigate the role of worker mobility within supply chain linkages. Gaining further understanding in what conditions worker mobility occur and modeling how this changes the environment increases our apprehension of how foreign MNEs impact the economy. Furthermore, applying the findings of Komatsua and Dhyne (2023) that 42% of job transitions in Belgium occur within supply chains highlights the role that linked-employee-employer data could play in methods extrapolating firm-to-firm linkage data. Last, studying supplier and buyer networks offers a vast amount of opportunities to model idiosyncratic firm level or industry level shocks that propagate a macroeconomic change, as described by Acemoglu et al. (2012). This helps anticipating and the mitigation of economic shocks, promoting stability and growth in an economy.

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8 Appendix A - Network reconstruction method

The reconstruction method for the Dutch firm network is extensively described in Buiten et al. (2021). This section will summarise the crucial steps and assumptions.

The dataset was developed to analyse the production network of the Netherlands at firm level. The method is a top down approach with the option of adding bottom up data (direct observed links). The algorithm is deterministic and will thus always provide the same estimated dataset. The basic idea of the methodology follows the following set-up.

1. Select all relevant firms from the Statistical business register.
2. Estimate intermediary supply and use per firm which is used to set-up the input/output tables per commodity.
3. Estimate for each commodity the probability that a specific supplying firm trades to a specific using firm
4. Use the estimated probabilities and distribute the total amount of intermediary transactions per commodity across each linkage
5. Aggregate over all commodities

It is crucial to understand how the number of links per firm is constructed. First, a lower bound is constructed where every using firm has only one supplier. Second, an adjustment factor is used to calibrate the method. Third, the total outdegree for each firm commodity combination is distributed using the relationship between firm size and the number of linkage found in previous literature. This distribution follows a power law and is defined as follows. The number of connections k for company i for turnover S:

$$S_i = \alpha_i k_i y \quad y \approx 1.3 \implies k_i = (S_i \alpha_i) 1y$$

$$\alpha_0 = (\sum S_i 1yks)y$$

y approximates the relationship between sales and the number of connection which is taken from Watanabe et al. (2013).

s see Watanabe et al. (2013)

k is not continuous, as k is discrete. Therefore, low turnovers may lead to $k = 0$. This is solved by using an algorithm that brackets and bisects k that results in values of α_0 being estimated as if k would be continuous. The method is deviated for commodities where a large number of suppliers is the norm, such as medicines, where doctors and hospitals likely use all products from many or even all suppliers.

The matching of supplying and using firms per commodity is done with a clearing procedure. The most likely firm linkage is estimated given the in- and outdegrees per firm per commodity and the given overall scores. The top X number of firms with the highest value of the overall score for a commodity group are picked. The outdegree for the matched supply firms is adjusted, which results in no firms being chosen more than their predicted outdegree. The overall scores are defined as follows:

$$\text{Overall score}_i = \alpha\text{Company Score}_i + (1-\alpha)\text{Distance score}_i + \text{Industry Score}_i + \text{Observed Relation score}_i$$

α is a weight with $\alpha \in [0, 1]$. Weights are based on the Belgian network(Dhyne & Duprez, 2016).

The company score is relative to all other companies supplying within the commodity. Defined as:

$$\text{Company Score} = 1 - \max(\log(\text{net turnover}_i - \log(\text{net turnover}_{max})), \text{Company Score} \in \{0, 1\}$$

The distance score is relative to the furthest possible partner. Defined as:

$$\text{Distance}_{i,use} = |(Lat_i - Lat_{use})| + |(Long_i - Long_{use})|$$

$$\text{Distance} = Distance_{i,use} \quad \forall i, use$$

$$\implies \text{Distance score}_i = \frac{\text{Distance}_{i,use}}{\max(\text{Distance})}, \text{Distance score}_i \in \{0, 1\}$$

The industry score is defined as follows:

$$\text{Industry score} = \begin{cases} \text{If sector has no trade in IO table} & -1 \\ \text{OW} & 0 \end{cases}$$

Lastly, the observed relation score is defined as follows:

$$\text{Observed Relation score} = \begin{cases} \text{If observed} & 1 \\ \text{If not observed} & 0 \end{cases}$$

9 Appendix B - Stylized facts of the Dutch business network

This appendix aims to recreate some stylized facts found by previous literature in order to assure that the extrapolated data resembles real observed datasets as used by the literature. The stylized facts of the papers are described in Alfaro (2016) and Bernard and Moxnes (2018), therefore the aim is to recreate and compare the facts and parameters. For an overview of the facts in this literature please view Bacilieri et al. (2023)

First, most firms have a low number of connections while few have a lot of connections. Firms below the 50th percentile have 24 linkage as suppliers and 36 as users. While the top 5 percentile has more than 5010 linkages as suppliers and 170 as users. As can be noted from figure 1, the distribution is heavy-tailed and resembles a Pareto distribution as in Alfaro (2016) and Bernard and Moxnes (2018). Bernard and Moxnes (2018) report an estimated slope of the CCDF with -1.50 for buyers and -1.32 for suppliers. Which is different to Alfaro (2016) with -0.73 for suppliers and -0.58 for buyers. Similar estimates are found by regressing the log CCDF on the log of the number of buyers or suppliers with -1.22 for suppliers and -0.83 for users and using the DAB data coefficients of -1.78 for suppliers and -0.65 for users are found. These estimates appear to be consistent with the results found in other literature analysed in Bacilieri et al. (2023).

Second, the correlation between size and the number of connections. For size the net sales is used. Figures 2 and 3 show a positive correlation between size and the number of connections a firm has. Alfaro (2016) find a slope of 0.89 for buyers and 1.2 for suppliers. A slope of 0.48 for buyers is found and 0.47 for suppliers. When using the DAB data the coefficients show a value of 0.87 for buyers and 0.11 for suppliers. This implies that for a 10% increase the number of buyers or suppliers the net sales increase with 4.8%, 4.7%, 8.7% and 1.1% respectively. Compared to Alfaro (2016) the coefficient for the suppliers is significantly smaller.

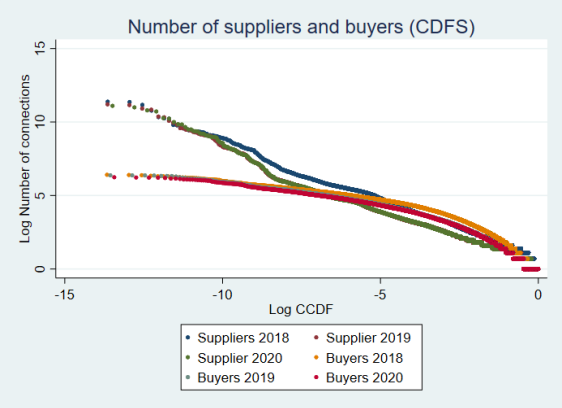
Third, the network exerts negative degree assortative. Figure 2 shows a positive degree associativity which is calculated as in Alfaro (2016). This graph seems to exert a positive degree assortativity. This is possibly due to the fact that outliers are affecting the results. However, the slope coefficient is -0.11 and -0.000000317 which suggests a negative degree assortative for users and very slight for suppliers. Bacilieri et al. (2023) suggests using a Pearson correlation coefficient, this test shows a assortativity of -0.0011 which is implies that their is negative degree associativity. Negative degree associativity implies that small

suppliers depend on large clients (Alfaro, 2016).

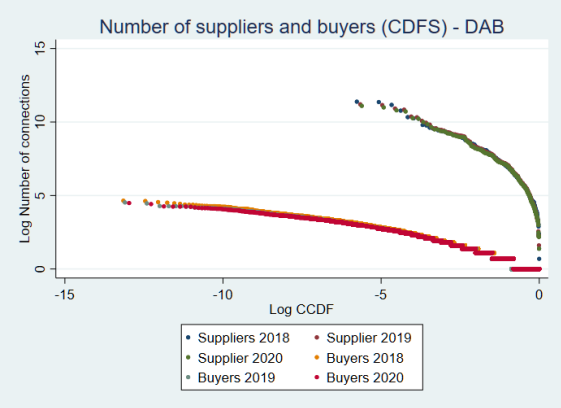
Last, to plot the labour productivity, value added per worker, of a firm and its number of linkages. Figure 7 and 8 appear to a positive correlation between the labour productivity of a firm and its number of linkages in both the extrapolated data and the DAB data.

Figure 1: Pareto distribution resemblance of the number of suppliers and buyers - DAB data

Full sample



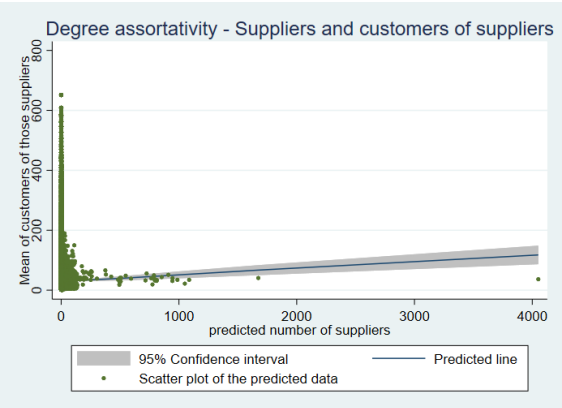
DAB sample



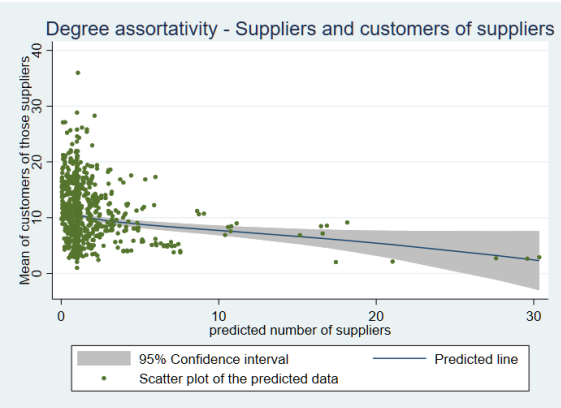
Notes: The figures plots the log number of linkages per year and the log complementary cumulative distribution function (CCDF).

Figure 2

Full sample



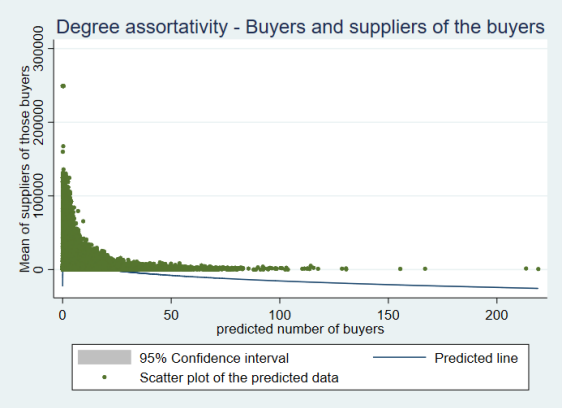
DAB sample



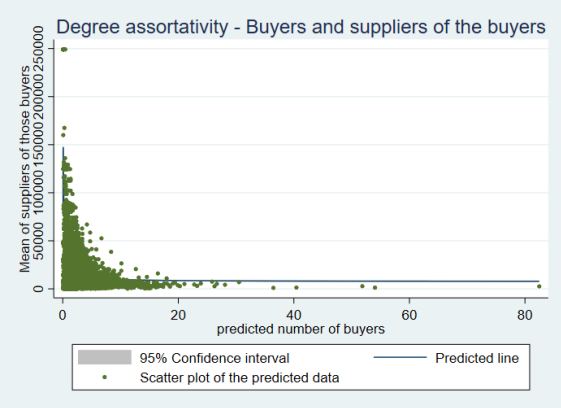
Notes: The figures capture a local polynomial regression with confidence levels at the 95% mark, the log number of supplier (outdegree) on the x axis and the log mean number of customers of the supplying firms on the y axis. The model controls for 4-digit sector codes, year and region FE, with a first order polynomial for the y variable

Figure 3: Degree assortativity of buyers and suppliers

Full sample



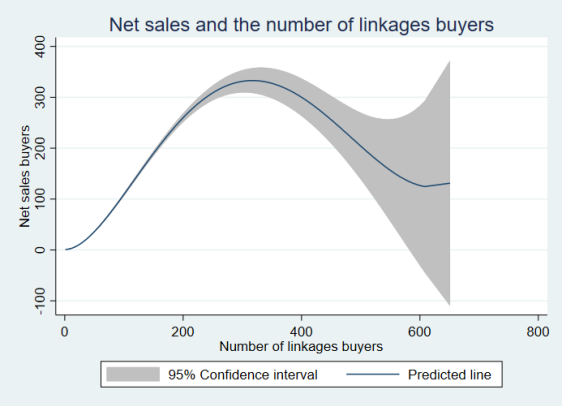
DAB sample



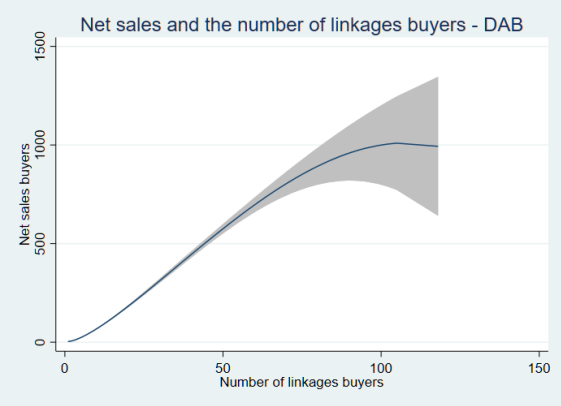
Notes: The figures capture a local polynomial regression with confidence levels at the 95% mark, the log number of buyers (indegree) on the x axis and the log mean number of supplier of the buyers on the y axis. The model controls for 4-digit sector codes, year and region FE, with a first order polynomial for the y variable

Figure 4: Correlation size and number of connections - buyers

Full sample



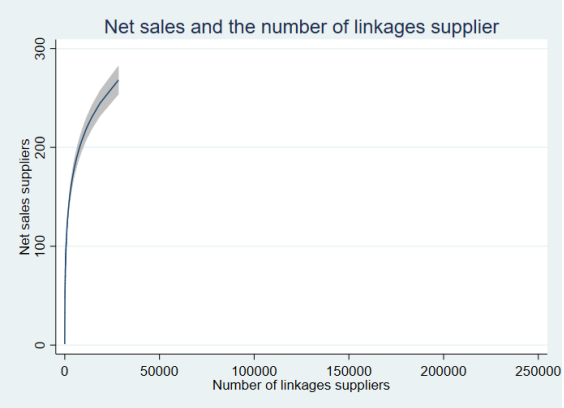
DAB sample



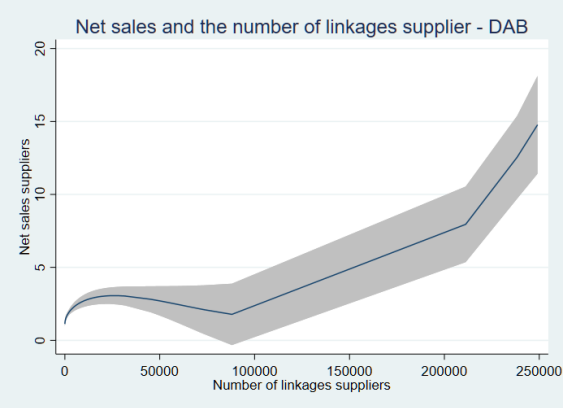
Notes: The figures capture a local polynomial regression with confidence levels at the 95% mark, the log number of buyers (indegree) on the x axis and the log firm net sales on the y axis. The model controls for 4-digit sector codes, year and region FE, with a third order polynomial for the y variable.

Figure 5: Correlation size and number of connections - suppliers

Full sample

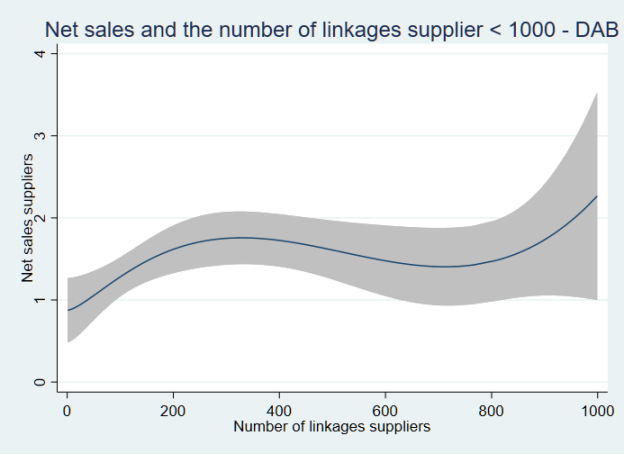


DAB sample



Notes: The figures capture a local polynomial regression with confidence levels at the 95% mark, the log number of suppliers (outdegree) on the x axis and the log firm net sales on the y axis. The model controls for 4-digit sector codes, year and region FE, with a third order polynomial for the y variable.

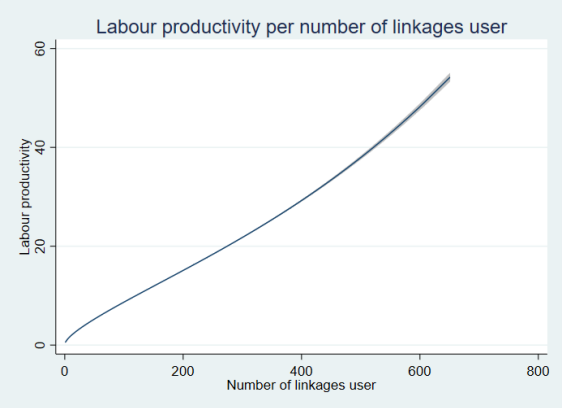
Figure 6: Correlation size and number of connections - suppliers - excluding extremes



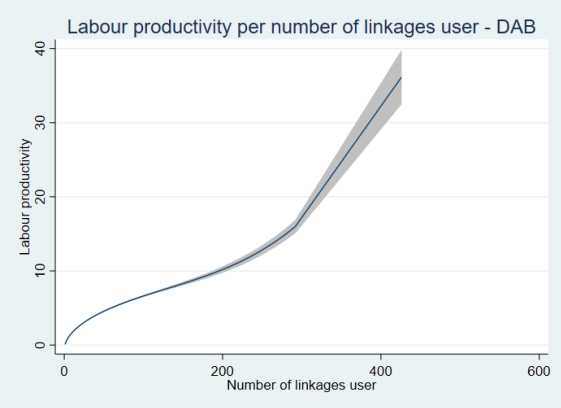
Notes: The figure captures a local polynomial regression with confidence levels at the 95% mark, the log number of supplier (outdegree) on the x axis and the log firm net sales on the y axis. The model controls for 4-digit sector codes, year and region FE, with a third order polynomial for the y variable.

Figure 7: Correlation value added and number of connections - users

Full sample



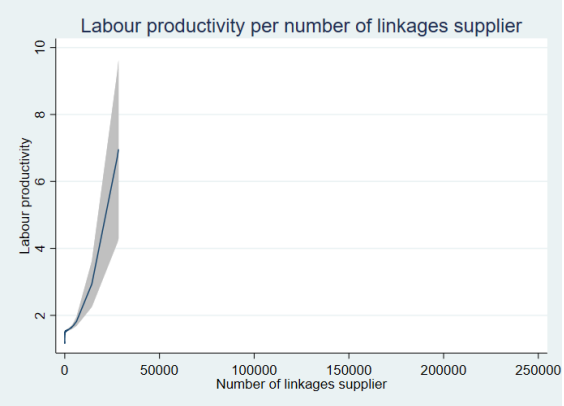
DAB sample



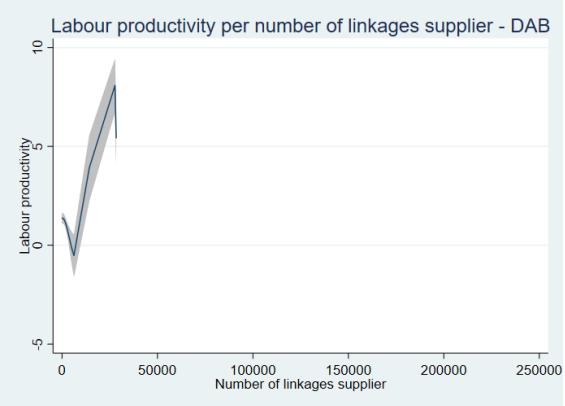
Notes: The figures capture a local polynomial regression with confidence levels at the 95% mark, the log number of supplier (outdegree) on the x axis and the log labour productivity (y axis). The model controls for 4-digit sector codes, year and region FE, with a third order polynomial for the y variable.

Figure 8: Correlation size and number of connections - suppliers

Full sample



DAB sample



Notes: The figures capture a local polynomial regression with confidence levels at the 95% mark, the log number of supplier (outdegree) on the x axis and the log labour productivity (y axis). The model controls for 4-digit sector codes, year and region FE, with a third order polynomial for the y variable.

10 Appendix C - TFP calculation and example visualisation of network structure

10.1 TFP calculations

Statistics Netherlands has not provided additional details on how the TFP variables are precisely calculated. It is assumed that this is done properly according to standard procedures.

To calculate the TFP the following Cobb-Douglas production function is used. The indexation of i, t is surpressed as each variable is calculated for each firm in a specific time period.

$$Y = AK^{\alpha}L^{\beta} \Leftrightarrow A = \frac{Y}{K^{\alpha}L^{\beta}}$$

Y is the value added for each firm in each time period. K represents the capital and L the labour with the respective ACF or GR weight α and β. A represents the productivity.

The growth accounting approach (TFP GR) decomposes output growth into contributions from input growth and TFP growth. To derive the TFP from the Cobb-Douglas function the production function is log-linearised.

$$\ln Y = \ln A + \alpha \ln K + \beta \ln L$$

α and β are estimated using an OLS regression representing the weights in the GR method.

The Ackerberg et al. (2015) method starts similar but uses a 2 stage process which includes a control function $\phi(.)$ which captures the endogeneity of the productivity term A. The first stage is represented by the following equation.

$$Y = \beta_0 + \alpha \ln L + \beta \ln K + \phi(A, \ln K) + \epsilon$$

To proxy A investments I is typically used. Then in the second stage a markov process is often assumed which is represented by the following equation.

$$A = g(A_{t-1}) + \xi$$

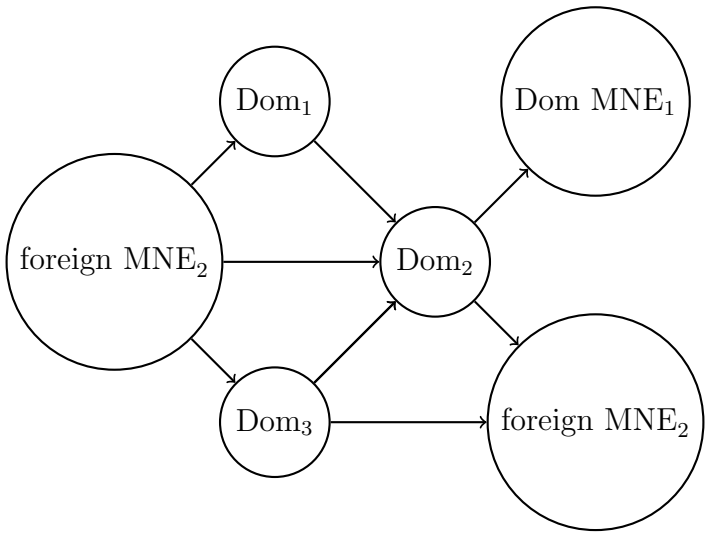
ξ captures the unexpected productivity shock and A_{t-1} captures the productivity of the

previous period. ξ is used to validate the robustness of the estimated elasticities in the first stage.

This explanation is simplified but captures the essence of how the TFP are calculated. Please refer to the original papers of Ackerberg et al. (2015) for more details. The information provided is used to explain differences found in the results which can be explained by the different methodology of the two TFP variables.

10.2 Graph visualisation - Indegree and Outdegree

Consider the following directed graph $G(V, E)_t$ in time period t.



The subsequent graph captures an example of a network structure. The indegree captures the total of incoming linkages. Domestic firm two has a total indegree of three as it has three firms supplying its operations and a total outdegree of two as domestic MNE one and foreign MNE two are buyers of domestic firm two. In order to calculate B_{it} or F_{it} one has to count the number of linkages the firm of interest has with each firm type. So domestic firm two has a total indegree with domestic firms of two and a total indegree with foreign MNEs of one and zero with domestic MNEs. The tables refer to this as 'number of linkages buying from domestic firms' for example. Idem, domestic firm two has a total outdegree with domestic firms of zero, and a outdegree of one with foreign MNEs and domestic MNEs. This is referred to in the tables as 'number of linkages supplying to foreign MNEs'.

11 Appendix D - Supporting results Brexit strategy

This appendix aims to provide supporting tables to the usage of Brexit variation. Furthermore, table 9-20 show the matching procedure statistics of each type of regression. The goal of the matching procedure is to achieve the best balance for a large number of observations (Ho et al., 2007).

The first statistic shows the Pseudo R squared of the matching procedure. The low value can be partially be explained by the rarity of the event and the matching based on the entire sample instead of a yearly basis. The propensity score tautology by Ho et al. (2007) suggests that, the effectiveness of the propensity score model is not indicated by its ability to fit the data but solely on the ability to balance the covariates. Therefore, the low Pseudo R squared value is not seen as an issue.

The second and third statistics shows a likelihood ratio Chi squared and the statistical significance of this estimate. A high value suggests that the covariates in the model are relevant and significantly associated with assignment of being affected by a Brexit leaving connection. All tables show a large value and are statistically significant, thus the covariates appear to be relevant.

The fourth and fifth statistics show the mean bias and the median bias. Both indicate that the average difference in the treated and control group is minimal. This implies that the matching procedure has successfully reduced the difference in covariates between the groups.

The sixth statistics shows a balancing property test. This test measures how well the matching balances the covariates between the firms affected by Brexit leavers and the control group. The benchmark of an adequately matched sample is perceived to below 25 as lower values indicate a better balanced procedure. All tables show a value below 25, indicating adequate balance of covariates.

The seventh statistic shows the ratio of variances of the propensity scores between the Brexit leaver affected firms and the control group after matching. The low value close to 1 suggests that the distribution of propensity scores is similar which indicates good overlap.

The eight statistics shows the percentage of variable balanced. A value of 100% indicates that the matching procedure was successfully in balancing all covariates which reduces the bias from observed cofounders. Some matching procedures with 10 neighbours were not entirely successful as the value is 67. The matching procedure is worse compared to models with 3 or 5 neighbours. Therefore, the 3 and 5 neighbour models are preferred.

	OLS			
	(1)	(2)	(3)	(4)
	ln Number of linkages supplying to Domestic firm	ln Number of linkages supplying to Domestic MNE	ln Number of linkages supplying to Foreign MNE	ln Number of linkages buying from Brexit firm
L.ln TFP ACF	0.0754***	-0.00602***	-0.0138***	-0.00271
	(0.00363)	(0.000766)	(0.00201)	(0.00245)
Size Classification	0.0169***	0.000964***	0.00476***	0.00708***
	(0.000214)	(0.0000451)	(0.000118)	(0.000144)
ln Imports	0.0186***	0.00267***	0.00961***	0.0114***
	(0.00101)	(0.000212)	(0.000557)	(0.000678)
ln Exports	0.0217***	0.00208***	0.00924***	0.00884***
	(0.00117)	(0.000246)	(0.000646)	(0.000787)
Constant	0.632***	0.0550***	0.185***	0.144***
	(0.0388)	(0.00818)	(0.0215)	(0.0261)
Observations	91568	91568	91568	91568
R-squared	0.0905	0.0132	0.0352	0.0409
Adjusted R-squared	0.0904	0.0131	0.0351	0.0408

Table 6: Reverse causality - correlation lagged productivity domestic firms and the number of connections

Notes: This table shows the results of an OLS regression of the number of connections and lagged TFP of domestic firms. Standard errors in parentheses. ***,**,* denote α at the 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
	ln # connections as supplier	ln # connections as buyer	ln # connections as supplier	ln # connections as buyer
Changed supplier UCI status to NL	0.253**	0.330**		
	(0.119)	(0.159)		
Changed UCI status to UK			0.197***	0.219***
			(0.0629)	(0.0758)
Size classification	0.0163***	0.0384***	0.0163***	0.0384***
	(0.0000597)	(0.0000717)	(0.0000597)	(0.0000717)
Constant	0.980***	0.891***	0.981***	0.891***
	(0.000908)	(0.00137)	(0.000908)	(0.00137)
Observations	2241100	1308439	2241100	1308439
R-squared	0.494	0.654	0.494	0.654
Adjusted R-squared	0.483	0.644	0.484	0.644
Firm FE	No	No	No	No
Sector#Region#Year	No	No	No	No

Table 7: Ultimate owner change and user and network size

Notes: This table shows the results of an OLS regression the number of linkages as supplier or buyers and whether the firm changed UCI from the Netherlands or the United Kingdom or vice versa. Region, year, and 4 digit sector code FE are used if Firm FE is not used. Standard errors in parentheses. Robust standard erorrs. ***,**,* denote α at the 1%, 5%, and 10%, respectively.

	Observations		Means		
Variable	**Brexit joiner firms**	**Control**	**Brexit joiner firms**	**Control**	**T-test**
TFP (ACF)	50.00	20650.00	67908.03	67445.61	-462.42 (-0.04)
Labour productivity (value added per worker)	52.00	21852.00	148921.19	164170.09	15248.89 (0.57)
Size class	55.00	23821.00	60.38	45.95	-14.43*** (-5.72)
Firm age in years	55.00	23821.00	23.44	20.45	-2.98 (-1.49)

Notes: Note that, out of the 146 Brexit joiners firms the characteristics are observed for 50.

Table 8: Descriptive Statistics: Brexit firms compared to foreign MNEs

	Ps R^2	LR chi^2	p>chi2	MeanBias	MedBias	B	R	%Var
Values	0.006	1589.21	0.000	1.1	0.9	17.9	1.00	100

Table 9: ACF TFP matching procedure statistics 1 neighbours propensity score matching strategy

	Ps R^2	LR chi^2	p>chi2	MeanBias	MedBias	B	R	%Var
Values	0.007	1812.99	0.000	1.1	0.8	19.0	1.11	100

Table 10: ACF TFP matching procedure statistics 3 neighbours propensity score matching strategy

	Ps R^2	LR chi^2	p>chi2	MeanBias	MedBias	B	R	%Var
Values	0.007	1910.71	0.000	1.1	0.9	19.5	1.15	100

Table 11: ACF TFP matching procedure statistics 5 neighbours propensity score matching strategy

	Ps R^2	LR chi^2	p>chi2	MeanBias	MedBias	B	R	%Var
Values	0.007	1989.86	0.000	1.2	0.9	19.8	1.29	67

Table 12: ACF TFP matching procedure statistics 10 neighbours propensity score matching strategy

	Ps R^2	LR chi^2	p>chi2	MeanBias	MedBias	B	R	%Var
Values	0.006	1598.21	0.000	1.1	0.9	17.9	1.00	100

Table 13: GR TFP matching procedure statistics 1 neighbours propensity score matching strategy

	Ps R^2	LR chi^2	p>chi2	MeanBias	MedBias	B	R	%Var
Values	0.007	1812.99	0.000	1.1	0.8	19.0	1.11	100

Table 14: GR TFP matching procedure statistics 3 neighbours propensity score matching strategy

	Ps R^2	LR chi^2	p>chi2	MeanBias	MedBias	B	R	%Var
Values	0.007	1910.71	0.000	1.1	0.9	19.5	1.15	100

Table 15: GR TFP matching procedure statistics 5 neighbours propensity score matching strategy

	Ps R^2	LR chi^2	p>chi2	MeanBias	MedBias	B	R	%Var
Values	0.007	1989.86	0.000	1.2	0.9	19.8	1.29	67

Table 16: GR TFP matching procedure statistics 10 neighbours propensity score matching strategy

	Ps R^2	LR chi^2	p>chi2	MeanBias	MedBias	B	R	%Var
Values	0.008	2242.03	0.000	1.1	0.8	20.4	1.76	67

Table 17: Labour productivity matching procedure statistics 1 neighbours propensity score matching strategy

	Ps R^2	LR chi^2	p>chi2	MeanBias	MedBias	B	R	%Var
Values	0.007	2014.97	0.000	1.1	0.8	19.9	1.12	100

Table 18: Labour productivity matching procedure statistics 3 neighbours propensity score matching strategy

	Ps R^2	LR chi^2	p>chi2	MeanBias	MedBias	B	R	%Var
Values	0.007	1991.21	0.000	1.1	0.8	19.7	1.14	100

Table 19: Labour productivity matching procedure statistics 5 neighbours propensity score matching strategy

	Ps R^2	LR chi^2	p>chi2	MeanBias	MedBias	B	R	%Var
Values	0.007	1994.60	0.000	1.1	0.9	19.6	1.29	100

Table 20: Labour productivity matching procedure statistics 10 neighbours propensity score matching strategy

12 Appendix E - Robustness check results

	OLS		Δ OLS	
	(1)	(2)	(3)	(4)
	ln TFP GR	ln TFP GR	D.ln TFP GR	D.ln TFP GR
ln Number of linkages buying from Domestic firms	0.264***	0.0893***	0.0918***	0.103***
	(0.00689)	(0.00679)	(0.00563)	(0.0109)
ln Number of linkages buying from Domestic MNEs	0.0449***	0.000835	-0.00551	-0.0118
	(0.00620)	(0.00722)	(0.00605)	(0.0135)
ln Number of linkages buying from Foreign MNEs	0.00821*	0.00767	0.00749*	0.0156**
	(0.00451)	(0.00516)	(0.00430)	(0.00780)
ln Number of linkages supplying to Domestic firms	0.00448	0.00891**	0.000938	0.00248
	(0.00399)	(0.00378)	(0.00340)	(0.00635)
ln Number of linkages supplying to Domestic MNEs	0.0199**	0.00774	0.00711	0.00235
	(0.00956)	(0.0106)	(0.00845)	(0.0158)
ln Number of linkages supplying to Foreign MNEs	0.0196***	0.00516	-0.000961	-0.00359
	(0.00440)	(0.00434)	(0.00371)	(0.00649)
Size Classification	-0.0147***	-0.00517***	-0.00357***	-0.00183*
	(0.000378)	(0.000611)	(0.000522)	(0.00103)
ln Imports	0.000703	-0.000738	-0.000318	-0.000242
	(0.000560)	(0.000523)	(0.000447)	(0.000927)
ln Exports	0.00689***	0.00100	0.000922	0.000420
	(0.000764)	(0.000703)	(0.000592)	(0.00111)
Constant	9.233***	9.426***	0.0945***	0.100***
	(0.0128)	(0.0310)	(0.00220)	(0.00451)
Observations	141466	127244	78560	63418
R-squared	0.742	0.946	0.147	0.520
Adjusted R-squared	0.723	0.903	0.0795	-0.134
Firm FE	No	Yes	No	Yes
Sector#Region#Year	Yes	Yes	Yes	Yes

Table 21: Robustness - The productivity of domestic firms and its linkages

Notes: This table shows the results of an OLS regression of equation 1 where the F_{it} is represented by the linkages as supplier (forward) and B_{it} by the linkages as buyer (backward). TFP is calculated using the Growth rate method. Region, year, and 2 digit sector code FE are used if Firm FE is not used. Standard errors in parentheses. Clustering of standard errors at 2 digit sector and region level. ***,**,* denote α at the 1%, 5%, and 10%, respectively.

	OLS		Δ OLS	
	(1)	(2)	(3)	(4)
	ln Labour productivity	ln Labour productivity	Δ ln Labour productivity	Δ ln Labour productivity
ln Number of linkages buying from Domestic firms	0.302***	0.0824***	0.0806***	0.0912***
	(0.00674)	(0.00660)	(0.00507)	(0.0104)
ln Number of linkages buying from Domestic MNEs	0.0560***	-0.000333	-0.00804	-0.0187
	(0.00624)	(0.00685)	(0.00536)	(0.0127)
ln Number of linkages buying from Foreign MNEs	0.0458***	0.0104**	0.0121***	0.0175**
	(0.00447)	(0.00492)	(0.00387)	(0.00744)
ln Number of linkages supplying to Domestic firms	0.00737*	0.00865**	0.00522*	0.00168
	(0.00411)	(0.00370)	(0.00305)	(0.00580)
ln Number of linkages supplying to Domestic MNEs	0.0206**	0.00557	0.00787	0.00374
	(0.00952)	(0.0104)	(0.00796)	(0.0151)
ln Number of linkages supplying to Foreign MNEs	0.0184***	0.00550	0.00286	-0.00101
	(0.00447)	(0.00414)	(0.00335)	(0.00624)
Size Classification	-0.0179***	-0.00415***	-0.00250***	-0.000483
	(0.000386)	(0.000594)	(0.000480)	(0.000986)
ln Imports	0.00386***	-0.000752	-0.000419	-0.000410
	(0.000560)	(0.000517)	(0.000414)	(0.000887)
ln Exports	0.0100***	0.00103	0.00114**	0.000442
	(0.000764)	(0.000675)	(0.000539)	(0.00103)
Constant	10.77***	10.99***	-0.0211***	-0.0196***
	(0.0127)	(0.0300)	(0.00186)	(0.00410)
Observations	144682	130244	80643	65282
R-squared	0.320	0.859	0.141	0.506
Adjusted R-squared	0.273	0.747	0.0749	-0.164
Firm FE	No	Yes	No	Yes
Sector#Region#Year	Yes	Yes	Yes	Yes

Table 22: Robustness - The productivity of domestic firms and its linkages

Notes: This table shows the results of an OLS regression of equation 1 where the F_it is represented by the linkages as supplier (forward) and B_{it} by the linkages as buyer (backward). Labour productivity is calculated by va/L. Region, year, and 2 digit sector code FE are used if Firm FE is not used. Standard errors in parentheses. Clustering of standard errors at 2 digit sector and region level. ***,**,* denote α at the 1%, 5%, and 10%, respectively.

	OLS		Δ OLS	
	(1)	(2)	(3)	(4)
	ln TFP GR	ln TFP GR	Δln TFP GR	Δln TFP GR
ln Normalised weighted linkages buying from Domestic firm	-0.0768***	-0.0247***	-0.0217***	-0.0136***
	(0.00305)	(0.00302)	(0.00231)	(0.00417)
ln Normalised weighted linkages supplying to Domestic firm linkages	-0.122***	-0.0384***	-0.0335***	-0.0226***
	(0.00282)	(0.00271)	(0.00205)	(0.00349)
ln Normalised weighted linkages buying from Domestic MNE linkages	0.00656	0.0140**	0.0150***	0.0155
	(0.00663)	(0.00662)	(0.00537)	(0.0112)
ln Normalised weighted linkages supplying to Domestic MNE linkages	0.0400**	0.0215	0.0333**	0.0408*
	(0.0179)	(0.0162)	(0.0130)	(0.0210)
ln Normalised weighted linkages buying from Foreign MNE linkages	0.0603***	0.0159***	0.0116***	-0.000454
	(0.00437)	(0.00474)	(0.00380)	(0.00798)
ln Normalised weighted linkages supplying to Foreign linkages	0.0773***	0.0113*	0.00911*	0.00504
	(0.00571)	(0.00635)	(0.00480)	(0.00789)
Size Classification	-0.00736***	-0.00439***	-0.00299***	-0.00176*
	(0.000221)	(0.000629)	(0.000529)	(0.00104)
ln Imports	0.00406***	-0.000701	-0.000385	-0.000206
	(0.000564)	(0.000526)	(0.000441)	(0.000935)
ln Exports	0.00435***	0.00103	0.000941	0.000338
	(0.000766)	(0.000719)	(0.000600)	(0.00112)
Constant	9.903***	9.737***	0.0627***	0.0636***
	(0.00900)	(0.0227)	(0.000916)	(0.00186)
Observations	138761	124139	76501	61550
R-squared	0.737	0.946	0.151	0.517
Adjusted R-squared	0.718	0.903	0.0834	-0.144
Firm FE	No	Yes	No	Yes
Sector#Region#Year	Yes	Yes	Yes	Yes

Table 23: Robustness - The productivity of domestic firms and weight of linkages

Notes: This table shows the results of an OLS regression equation 1 where F'_{it} and B'_{it} is used. TFP is calculated using the Growth rate method. Region, year, and 2 digit sector code FE are used if Firm FE is not used. Standard errors in parentheses. Clustering of standard errors at 2 digit sector and region level. ***,**,* denote α at the 1%, 5%, and 10%, respectively.

	OLS		Δ OLS	
	(1)	(2)	(3)	(4)
	ln Labour productivity	ln Labour productivity	Δ ln Labour productivity	Δ ln Labour productivity
ln Normalised weighted linkages buying from Domestic firm	-0.0906***	-0.0249***	-0.0225***	-0.0144***
	(0.00319)	(0.00304)	(0.00222)	(0.00413)
ln Normalised weighted linkages supplying to Domestic firm linkages	-0.139***	-0.0378***	-0.0338***	-0.0240***
	(0.00281)	(0.00265)	(0.00199)	(0.00343)
ln Normalised weighted linkages buying from Domestic MNE linkages	0.0183***	0.0145**	0.0169***	0.0175
	(0.00663)	(0.00677)	(0.00544)	(0.0108)
ln Normalised weighted linkages supplying to Domestic MNE linkages	0.0516***	0.0241	0.0299**	0.0381*
	(0.0174)	(0.0155)	(0.0121)	(0.0206)
ln Normalised weighted linkages buying from Foreign MNE linkages	0.0675***	0.0155***	0.0113***	-0.00101
	(0.00452)	(0.00483)	(0.00378)	(0.00775)
ln Normalised weighted linkages supplying to Foreign linkages	0.0881***	0.0106*	0.00933**	0.00547
	(0.00548)	(0.00613)	(0.00468)	(0.00767)
Size Classification	-0.00850***	-0.00330***	-0.00185***	-0.000305
	(0.000236)	(0.000610)	(0.000482)	(0.000983)
ln Imports	0.00872***	-0.000736	-0.000399	-0.000317
	(0.000578)	(0.000518)	(0.000405)	(0.000885)
ln Exports	0.00763***	0.000883	0.00103*	0.000421
	(0.000774)	(0.000696)	(0.000547)	(0.00104)
Constant	11.54***	11.28***	-0.0512***	-0.0517***
	(0.00949)	(0.0220)	(0.000860)	(0.00176)
Observations	141831	126978	78426	63226
R-squared	0.289	0.859	0.151	0.506
Adjusted R-squared	0.239	0.747	0.0837	-0.166
Firm FE	No	Yes	No	Yes
Sector#Region#Year	Yes	Yes	Yes	Yes

Table 24: Robustness - The productivity of domestic firms and weight of linkages

Notes: This table shows the results of an OLS regression equation 1 where F_it' and B_it' is used. Labour productivity is calculated by va/L. Region, year, and 2 digit sector code FE are used if Firm FE is not used. Standard errors in parentheses. Clustering of standard errors at 2 digit sector and region level. ***,**,* denote α at the 1%, 5%, and 10%, respectively.

	Δ OLS			
	(1)	(2)	(3)	(4)
	D.ln Labour	D.ln Labour	D.ln Capital	D.ln Capital
ln Number of linkages supplying to Brexit firms	-0.000276	0.000465	-0.00793	-0.0251
	(0.00138)	(0.00249)	(0.0106)	(0.0263)
First time supplying Brexit firm	0.00612***	0.0000654	0.00675	0.0133
	(0.00155)	(0.00247)	(0.0129)	(0.0264)
ln Number of linkages buying from Brexit firms	0.0227***	0.0101***	0.0134	-0.0174
	(0.00134)	(0.00172)	(0.00852)	(0.0161)
Size Classification	0.00721***	-0.00172***	0.0163***	0.00670**
	(0.000252)	(0.000421)	(0.00141)	(0.00274)
ln Imports	0.000110	0.000209	-0.00160	-0.00139
	(0.000152)	(0.000276)	(0.00127)	(0.00282)
ln Exports	-0.000210	0.00000556	0.00126	-0.000764
	(0.000179)	(0.000298)	(0.00160)	(0.00329)
Constant	0.0102***	0.0112***	0.0622***	0.0493***
	(0.000393)	(0.000598)	(0.00278)	(0.00586)
Observations	81090	65526	81266	65656
R-squared	0.129	0.654	0.0740	0.419
Adjusted R-squared	0.0621	0.185	0.00276	-0.366
Firm FE	No	Yes	No	Yes
Sector#Region#Year	Yes	Yes	Yes	Yes

Table 25: The inputs factors of productivity of domestic firms and Brexit linkages

Notes: This table shows the results of an OLS regression of equation 2. Region, year, and 2 digit sector code FE are used if Firm FE is not used. Standard errors in parentheses. Clustering of standard errors at 2 digit sector and region level. ***,**,* denote α at the 1%, 5%, and 10%, respectively.

	OLS
	(1)
	ln TFP ACF
Random integer Brexit outdegree	0.00000702
	(0.0000148)
Random integer Brexit indegree	-0.000126
	(0.000188)
Size Classification	-0.00443***
	(0.000554)
ln Imports	0.000339
	(0.000508)
ln Exports	0.000468
	(0.000626)
Constant	10.37***
	(0.0203)
Observations	146853
R-squared	0.881
Adjusted R-squared	0.791
Firm FE	Yes
Sector#Region#Year	Yes

Table 26: Spurious correlation test - Placebo test - Random brexit linkages and the productivity of domestic firms

Notes: This table shows the results of an OLS regression. The placebo test create a random uniform integer between 0 and the max of the original variable. Region, year, and 2 digit sector code FE are used if Firm FE is not used. Standard errors in parentheses. Clustering of standard errors at 2 digit sector and region level. ***,**,* denote α at the 1%, 5%, and 10%, respectively.

	OLS		Δ OLS	
	(1)	(2)	(3)	(4)
	ln TFP GR	ln TFP GR	Δ ln TFP GR	Δ ln TFP GR
Panel A: 1 neighbour				
ln Number of linkages buying from Brexit firms	0.0126	0.0127	0.0071	-0.0013
	(0.0095)	(0.0095)	(0.0076)	(0.0146)
ln Number of linkages supplying to Brexit firms	0.0048	-0.0015	-0.0081	-0.0267
	(0.0095)	(0.0124)	(0.0102)	(0.0250)
First time supplying a Brexit firm	.	0.0143	0.0194	0.0350
		(0.0123)	(0.0074)	(0.0224)
Adjusted R-squared	0.5950	0.5950	0.1013	-0.2044
Panel B: 3 neighbours				
ln Number of linkages buying from Brexit firms	0.0068	0.0068	0.0028	-0.0036
	(0.0065)	(0.0065)	(0.0054)	(0.0101)
ln Number of linkages supplying to Brexit firms	0.0098	0.0115	0.0053	-0.0006
	(0.0063)	(0.0080)	(0.0070)	(0.0177)
First time supplying a Brexit firm	.	-0.0040	0.0029	0.0115
		(0.0080)	(0.0068)	(0.0151)
Adjusted R-squared	0.7135	0.7135	0.1102	-0.2070
Panel C: 5 neighbours				
ln Number of linkages buying from Brexit firms	0.0082	0.0082	0.0030	-0.0045
	(0.0055)	(0.0055)	(0.0046)	(0.0086)
ln Number of linkages supplying to Brexit firms	0.0094	0.0117	0.0070	0.0061
	(0.0053)	(0.0067)	(0.0058)	(0.0141)
First time supplying a Brexit firm	.	-0.0052	0.0015	0.0052
		(0.0066)	(0.0058)	(0.0126)
Adjusted R-squared	0.7577	0.7577	0.1060	-0.1958
Panel D: 10 neighbours				
ln Number of linkages buying from Brexit firms	0.0079	0.0079	0.0018	-0.0028
	(0.0044)	(0.0044)	(0.0036)	(0.0066)
ln Number of linkages supplying to Brexit firms	0.0075	0.0079	0.0065	0.0083
	(0.0040)	(0.0049)	(0.0042)	(0.0106)
First time supplying a Brexit firm	.	-0.0008	0.0010	0.0003
		(0.0054)	(0.0048)	(0.0103)
Adjusted R-squared	0.8079	0.8079	0.0818	-0.2102
Observations	86,988	86,988	54,551	45,838
Firm FE	Yes	Yes	No	Yes
Sector#Region#Year	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

Table 27: The productivity of domestic firms with propensity score matching and Brexit linkage variation

Notes: This table shows an OLS regression with propensity score matching. Controls include firm size, imports, exports. Furthermore, region, year, and 2 digit sector code FE are used if Firm FE is not used. Standard errors in parentheses. Clustering of standard errors at 2 digit sector and region level. ***, **, * denote α at the 1%, 5%, and 10%, respectively.

	OLS		Δ OLS	
	(1)	(2)	(3)	(4)
	ln Labour productivity	ln Labour productivity	Δ ln Labour productivity	Δ ln Labour productivity
Panel A: 1 neighbour				
ln Number of linkages buying from Brexit firms	-.0041887	-.0042048	-.0026332	.002108
	(.0061695)	(.0061706)	(.0049601)	(.0097625)
ln Number of linkages supplying to Brexit firms	-.0016365	-.0005581	.0009511	-.0060715
	(.0059578)	(.0076195)	(.0064511)	(.015807)
First time supplying a Brexit firm	.	-.0024482	-.0027861	.0017949
		(.0078181)	(-.0027861)	(.0141261)
Adjusted R-squared	0.4289	0.4289	0.0756	-0.2626
Panel B: 3 neighbours				
ln Number of linkages buying from Brexit firms	-.0006535	-.000654	-.0011518	.0005006
	(.0040255)	(.0040273)	(.0032686)	(.0063721)
ln Number of linkages supplying to Brexit firms	.0016282	.0016662	.0035029	.0078703
	(.0036798)	(.0047003)	(.0039889)	(.0101227)
First time supplying a Brexit firm	.	-.0000864	-.0033621	-.0074956
		(0.0049544)	(.0040955)	(.0091439)
Adjusted R-squared	0.4872	0.4872	0.0582	-0.2853
Panel C: 5 neighbours				
ln Number of linkages buying from Brexit firms	.0025081	.0025016	.0029822	.0036794
	(.0032715)	(.003271)	(.0026369)	(.0050555)
ln Number of linkages supplying to Brexit firms	.0020466	.0024809	.0036491	.0067971
	(.0029203)	(.0036976)	(.0030998)	(.0076304)
First time supplying a Brexit firm	.	-.0009859	-.0034771	-.0065214
		(.0038975)	(.0032039)	(.0069498)
Adjusted R-squared	0.5233	0.5233	0.0602	-0.2865
Panel D: 10 neighbours				
ln Number of linkages buying from Brexit firms	.0015016	.0014827	.0012422	.0008079
	(.0024802)	(.00248)	(.001962)	(.0036576)
ln Number of linkages supplying to Brexit firms	.0012682	.0025346	.0025836	.0029022
	(.0020932)	(.0026574)	(.0022365)	(.0057443)
First time supplying a Brexit firm	.	-.0028748	-.0031452	-.0026338
		(.0028455)	(.0023635)	(.0052382)
Adjusted R-squared	0.5881	0.5881	0.0818	-0.2547
Observations	86,988	86,988	54,551	45,838
Firm FE	Yes	Yes	No	Yes
Sector#Region#Year	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

Table 28: The productivity of domestic firms with propensity score matching and Brexit linkage variation

Notes: This table shows an OLS regression with propensity score matching. Controls include firm size, imports, exports. Furthermore, region, year, and 2 digit sector code FE are used if Firm FE is not used. Standard errors in parentheses. Clustering of standard errors at 2 digit sector and region level. ***,**,* denote α at the 1%, 5%, and 10%, respectively.