FDI, Forward Linkages and Services Inputs

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Abstract

This paper provides evidence of spillover effects from foreign direct investment (FDI) through forward linkages. Using granular information on the universe of firm-to-firm transactions and inward FDI in Rwanda, we find substantial and persistent effects on value-added, employment and productivity of domestic firms after beginning to source from foreign-owned enterprises. These effects are more pervasive than those associated with selling to foreign-owned firms – the backward linkages emphasised in the literature. Suggestive evidence reveals that foreign-owned firms provide intermediate higher quality inputs, and that purchases of business and professional services from foreign firms have a positive effect on the performance of domestic firms.

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1 Introduction

Foreign direct investment (FDI) is widely considered to benefit host countries although it is well understood that both the prospects of attracting FDI and its effects on aggregate performance of host countries is influenced by the quality of governance and institutions.[1] Expected benefits may stem from greater competition within sectors, higher quality, lower priced or new products that are produced by foreign firms, and creation of new job opportunities and demand for skilled workers (Javorcik 2015). Benefits can also arise from backward linkages, reflected in domestic firms becoming suppliers to foreign investors, with associated potential for technology transfers and upgrading to satisfy quality and other performance standards required by foreign firms. Yet another potential source of benefits to domestic firms are forward linkages. By sourcing goods and services from foreign firms, domestic enterprises may obtain higher quality inputs that improve their performance.

Although the various channels through which FDI may benefit host countries have induced many developing countries to establish investment promotion agencies to facilitate inward FDI and provide investment incentives (Harding and Javorcik 2011), granular empirical evidence on the sign, magnitude and channels of spillovers from inward FDI into developing countries for domestic firms remains mixed (Alfaro 2017; Javorcik 2018; Garetto, Pavcnik, and Ramondo 2025). This is at least partly due to the fact that interactions with foreign firms that have established facilities in a country are difficult to observe and measure. Much of the literature using firm-level data has focused on backward linkages. The potential benefits to domestic firms that become suppliers to foreign-owned enterprises is a well established source of productivity gains from FDI, particularly in the context of manufacturing in emerging and developed economies. This is commonly thought to be due to higher quality standards of these foreign-owned customers as well as learning effects from interacting with them. Recent work by Alfaro-Urena, Manelici, and Vasquez (2022), for example, documents direct evidence of backward linkages in Costa Rica, where foreign firms establish production facilities in order to export to global markets.

With some notable exceptions, e.g., Fernandes and Paunov (2012), forward linkages have received less attention than backward linkages, despite being theoretically relevant and often observed in the context of low-income countries (Havranek and Irsova 2011; Garetto, Pavcnik, and Ramondo 2025). Channels for FDI spillovers are likely to vary, depending on country contexts and the intent of foreign investors. If investment is motivated by selling into local or regional markets (so-called market-seeking FDI) foreign firms may build different relationships with local suppliers and customers than if FDI is export-oriented, motivated by the availability of local input factors. Such efficiency-seeking FDI may be associated with incentives to create relationships with local suppliers and share – whether tacitly or

1. There is a huge literature on FDI and growth dating back to the 1990s that investigates the determinants of FDI flows and their association with economic growth, see e.g., Blomstrom, Lipsey, and Zegan (1996) and Borensztein, Gregorio, and Lee (1998).

explicitly – knowledge to improve suppliers performance so as to reduce production costs.

Market-seeking FDI is mainly concerned with meeting local demand for products and services, some of which will be intermediate inputs. Analogous to the literature emphasizing the positive effects of input trade liberalization in which products that were previously unavailable in the local markets or of inferior quality and/or higher cost (e.g., De Loecker and Goldberg 2014), FDI may be an instrument through which similar benefits can arise. If so, market seeking FDI may generate knowledge spillovers that improve the performance of domestic firms that buy intermediate goods and/or services from foreign firms.

Forward linkages are likely to be particularly important for services given the limited tradability of many services. The trade literature has documented that FDI is an important "mode of supply" for firms to provide services to foreign clients. The intangibility and non-storability of many services implies there is "proximity burden" requiring seller and buyer (provider and consumer) to be in the same place (Francois and Hoekman 2010). FDI in services therefore often will be market seeking (Kolstad and Villanger 2008). Even if the proximity constraint is not binding, e.g., because a service can be supplied digitally, firms may prefer to establish a local presence in the market for business reasons.[2]

In this paper, we focus on Rwanda, a small land-locked country in Sub-Saharan Africa that has actively promoted inward FDI and seen a surge in foreign investment in the past decade. Although Rwanda is a member of a common market, the East African Community (EAC), its land-locked geography and lack of rail connections to deep-water ports implies that it is an unlikely candidate for efficiency-seeking, export-oriented investment in manufacturing industries. Instead, FDI can be expected to target local and regional (EAC) markets, and export-oriented FDI to be natural resource-based (e.g., FDI in coffee and tea) or services-centred. Exporting services is an element of Rwanda's development strategy, reflected in support for investment in conference and convention facilities that target the global market (RDB 2014).

We exploit rich information from the universe of firm-to-firm transactions based on VAT declarations provided by the Rwanda Revenue Authority (RRA). These data are matched with registries listing inward foreign investors provided by the Rwanda Development Board (RDB), the national investment promotion agency, using a common anonymized tax code. This permits us to identify all transactions involving domestic and foreign firms, both as buyers and suppliers. Our treatment of interest is the first time a domestic firm buys inputs from a foreign firm, establishing a *forward linkage*. To understand whether buying from foreign firms has implications for future performance, we match VAT data with (a) financial data from Corporate Income Tax (CIT) declarations; (b) employment data from the Pay As You Earn (PAYE) database; and (c) export and import transactions from the Rwanda

2. For example, Stalkamp, Chen, and Li (2023) document that even "born digital" firms have incentives to engage in FDI in target markets. WTO (2024) Statistics on international trade in services by mode of supply show that sales through foreign affiliates (FDI or "mode 3" in WTO speak) continue to be much larger than cross border trade in services.

customs authorities.[3] The data span the period 2013-2022, covering a total of around 18,000 firms, 2,656 of which are foreign-owned.[4]

To address endogeneity concerns, we follow the recent literature that analyse similar types of administrative data as ours, e.g., Alfaro-Urena, Manelici, and Vasquez (2022) and Amiti et al. (2024), and employ an event study approach, paying specific attention to the issue of staggered treatment and pre-trends (selection). To do this, we leverage the large pool of "untreated" firms in the VAT data that do not buy from foreign firms and use the Synthetic Control Difference-in-Differences approach developed by Arkhangelsky et al. (2021) for estimation. Since our panel is unbalanced and focusing on a balanced panel would mean dropping a large number of observations, we extend their approach to be applicable to an unbalanced setting. We do this by collecting cohorts of treated units with the same data availability and identify for each cohort the set of valid control units under the staggered treatment setting. We apply the method in Arkhangelsky et al. (2021) to this subset of data and aggregate the treatment effects into horizon-specific effects by weighting them by the number of treated units used in every cohort.

Our results indicate that forward linkages are the dominant channel through which FDI generates spillovers for domestic firms in Rwanda. Firms that start sourcing from foreign-owned suppliers see an increase in value-added by around 30% and employment by around 10% on average. Such increases are persistent. We also document that forward linkages are strongest for interactions with foreign firms providing services, especially those with high skill content, such as consulting (business and professional services), and for interactions with foreign wholesalers – a channel for domestic firms to acquire foreign intermediate inputs and technologies. Overall, we show that sourcing from foreign firms is more conducive to improvements in performance relative to sourcing solely from domestic suppliers or from backward linkages to foreign firms. Results are robust to a battery of checks, including alternative methods, cuts to the sample and definitions of the treatment. In the final part of the paper, we explore some of the potential mechanisms to explain this relationship. We show in particular that the mix of goods offered by foreign firms is of higher quality relative to domestic suppliers. Moreover, we find that foreign firms dominate in several sectors providing some specific intermediate services–notably data centres, web portals and accounting and management consulting services. Such services are difficult to import, are typically needed by domestic firms and may not be available up to certain standards, in low-income contexts. Last, we also find that inputs sourced from foreign firms are complementing domestically sourced inputs, i.e. they do not crowd-out domestic suppliers.

Contribution to the literature. We add to extant research on FDI spillover effects in developing countries (Alfaro 2017; Garetto, Pavcnik, and Ramondo 2025). Relative to a previous wave of studies estimating backward linkages at the sectoral level (Javorcik 2004), more

3. Data sources are described in the next Section.

4. Of these 18,000 firms, roughly 10,000 (8,455 domestic and 1,491 foreign-owned) are observed for at least four years as required by our main identification strategy.

recent research exploits firm-to-firm transaction data to provide more robust evidence on the occurrence and the effects of linkages between domestic and foreign firms. As mentioned, much of the firm-level research continues to focus predominantly on measuring and evaluating the implications of backward linkages. This literature finds evidence of positive spillovers on different dimensions of domestic firm performance (e.g. Alfaro-Urena, Manelici, and Vasquez 2022; Kee 2015; Masso and Vahter 2023; Carballo et al. 2023; Amiti et al. 2024).[5] Research on African countries has also tended to focus on backward linkages, finding evidence of positive relationships (Amendolagine et al. 2013; Bwalya 2006) or investigates intra-industry horizontal spillovers on domestic firms and workers (e.g. Abebe, McMillan, and Serafinelli 2022; Toews and Vezina 2022; Hoekman, Sanfilippo, and Tambussi 2025; Olurotimi, Foltz, and Traore 2025).

Evidence on the effects of firm-to-firm forward linkages in African countries is largely limited to surveys. An example is a survey on multinationals and domestic firms in African and Asian countries by Newman et al. (2019), showing that forward linkages are more frequent than backward linkages, and are likely to associated with transfer of knowledge and/or technology. Consistent with these stylized facts, we document that both backward and forward linkages between foreign and domestic firms are widespread in Rwanda.

By showing that FDI in services spurs domestic firms performance via forward linkages, we also contribute to the literature on FDI as a mode of supply for services and the role of forward linkages between FDI in services and domestic firms, complementing earlier work on more developed economies (Arnold, Javorcik, and Mattoo 2011; Fernandes and Paunov 2012). As noted, services differ from FDI in manufacturing or natural resource based sectors insofar as many services cannot be easily exported. FDI in the service sector is therefore market-seeking to a much greater extent than in goods-producing activities. Many services are specialised intermediate inputs for other economic activities. This implies that in the context of countries receiving FDI in services, spillovers through forward-linkages can be expected to play a much larger role than spillovers through backward-linkages. This is particularly so for high-skilled business and professional services, such as consulting, that act as a source of knowledge on business processes, management practices and use of new technologies (Bloom et al. 2013).[6]

Finally, the paper makes a methodological contribution by extending the Synthetic Control (SC) difference-in-differences method (Arkhangelsky et al. 2021) to be applicable to unbalanced panels without gaps. It applies the SC method with a normalisation term in presence of a large number of potential control units (firms) as discussed in Abadie and l'Hour (2021). This yields a data-driven way to find useful control-units for the treated

5. For example, Amiti et al. (2024) examine firm-to-firm relationships in Belgium and find evidence of backward linkages from selling to FDI firms, domestic superstar firms and exporters.

6. Hoekman, Sanfilippo, and Tambussi (2025) find that the entry of foreign firms in high-value added services (e.g. business services) contributes to shifts in the composition of the labour force towards more skilled workers.

without relying on explicit matching functions.

The remainder of the paper proceeds as follows. Section 2 describes the data sources. Section 3 describes foreign investment activity in Rwanda and provides some descriptive evidence of the structure of FDI in the country. Section 4 provides describes our estimation procedure and presents the main results by contrasting spillovers through forward-linkages against spillovers through backward linkages from FDI. Section 5.2 then contextualises these results by decomposing the effect into spillover effects from FDI in different sectors of the economy. Section 7 concludes.

2 Data

We use administrative data from Rwanda to construct a panel of the universe of formal firms in Rwanda from 2013 to 2022. The data contains firm-level information on firms' balance sheets from Corporate Income Tax (CIT) data and Value-Added Tax (VAT) data, which allows us to identify firms' income, production costs and value-added at an annual frequency. It also covers data on formal employment and wage bills from Social Security Pay-As-You-Earn (PAYE) data. Further information at the firm-level includes the economic sector at the 4-digit ISIC4-level and geographic location of the firm from the tax register. Furthermore, we observe price-and quantity level information of imports and exports of goods effectuated by a firm using detailed customs data. Firms are identified across datasets using a common anonymised tax ID.

We also observe firm-to-firm transactional information from VAT sales- and purchase annexes. This data includes information on sales and purchases between businesses in terms of transaction values but does not provide reliable information on quantities or nature of goods and services traded. It does however include sales of both goods and services. This allows us to identify the interactions between all domestic firms during the observation period and serves as our main tool of identifying interactions of domestic with foreign firms. We aggregate transactions between firms at the annual level.

We identify foreign firms using two strategies. First, we have access to a register of FDI projects from the Onestop Centre managed by the Rwanda Development Board, the country's investment promotion agency. Registration as an FDI project is voluntary for foreign firms starting operations in Rwanda but is a prerequisite to access investment incentives outlined in the Law on Investment Promotion and Facilitation.[7] The second source of identifying foreign firms is a dataset on foreign ownership of firms maintained by the RDB and the Registrar General of Rwanda. This dataset comprises the ownership structure of all firms registering for operations in Rwanda with at least one shareholder who is a foreign

7. This law provides for several incentives that apply to any registered investor, e.g., exemption from capital gains, VAT exemptions and refunds, time-bound corporate or property income tax holidays or rate reductions, accelerated depreciation for investments in priority sectors, visa-related and employee work permit provisions.

national or company. Both datasets can be linked to our remaining data using the tax ID. For our main specification, we rely on the broader definition of foreign ownership as captured by the ownership structure recorded by the RDB and the Registrar General. We provide robustness checks considering only the more restricted set of foreign-owned firms that went through the voluntary registration process.

Our sample covers those firms for which we are able to successfully link the CIT dataset, information on firm-sectors, and VAT-annexes. In 2022, the total value-added generated by firms in our final sample covered roughly one third of Rwanda's GDP. This implies that we are able to conduct our analysis on a substantial part of the Rwandan economy despite the very high data-requirements we impose. Since foreign firms predominantly interact with formal domestic firms, limiting our attention to the formal economy of Rwanda captures the main channels of spillovers.

The coverage of employment data from the PAYE dataset is less extensive since informal employment is a more prevalent phenomenon than informal business activity. Data from the national Labour Force Surveys (LFS) allow us to infer that in 2021 the employment reported in the PAYE dataset and thus included in our sample accounted for roughly 5% of employment in Rwanda in that year. This corresponds approximately to the share of formal employment in the LFS.

3 Foreign Investment in Rwanda

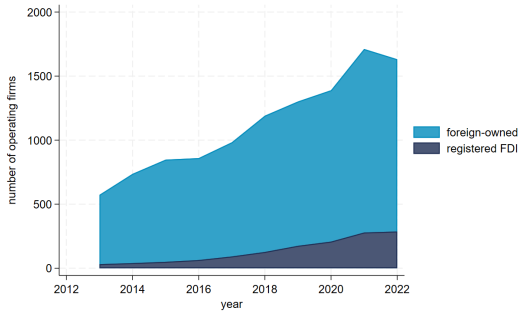
Rwanda has seen a strong influx of FDI in recent years. Figure 1 shows the trend in the number and business income of foreign firms active in Rwanda throughout the sample.[8] The number of foreign firms grew threefold in the past decade - roughly mirroring the growth in the number of formal firms reporting positive business income in Rwanda.[9] The business income generated by foreign firms has also increased, comprising 21% of business income reported by formal businesses in Rwanda in 2022 compared to 12% in 2013.

8. Here, we consider a firm to be active if it reported positive business income on its CIT filing.

9. The number of firms in our sample grew from about 3.600 in 2013 to about 12.500 in 2022. Of these firms, about 1.650 were foreign-owned in 2022, up from 575 in 2013.

Figure 1: Foreign firms in Rwanda

(a) Number of foreign-owned operating firms



(b) Business income of all operating firms

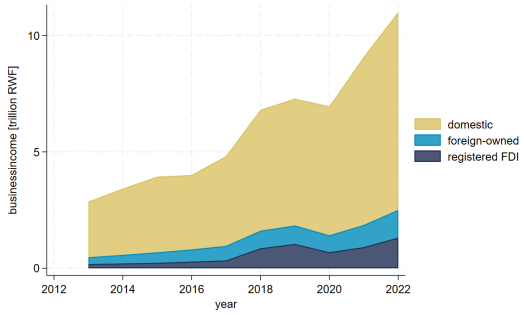


Figure 2 reports the value-added of active firms in 2022 by economic sector and ownership status. The figure includes both FDI notified to the RDB and foreign-owned firms – those that appear in the register of foreign-owned firms but have not gone through the voluntary FDI-registration process with the RDB. Some 300 of the more than 2,600 foreign firms active during the sample period were engaged in manufacturing activities. These firms generate over half of manufacturing value added and about one quarter of total foreign-owned value-added. While FDI in manufacturing is important, the majority of FDI firms in Rwanda are active in other sectors, accounting for substantial sectoral value added shares in financial, wholesale and other services.

Figure 2: Active firms in 2022 by economic sector and ownership

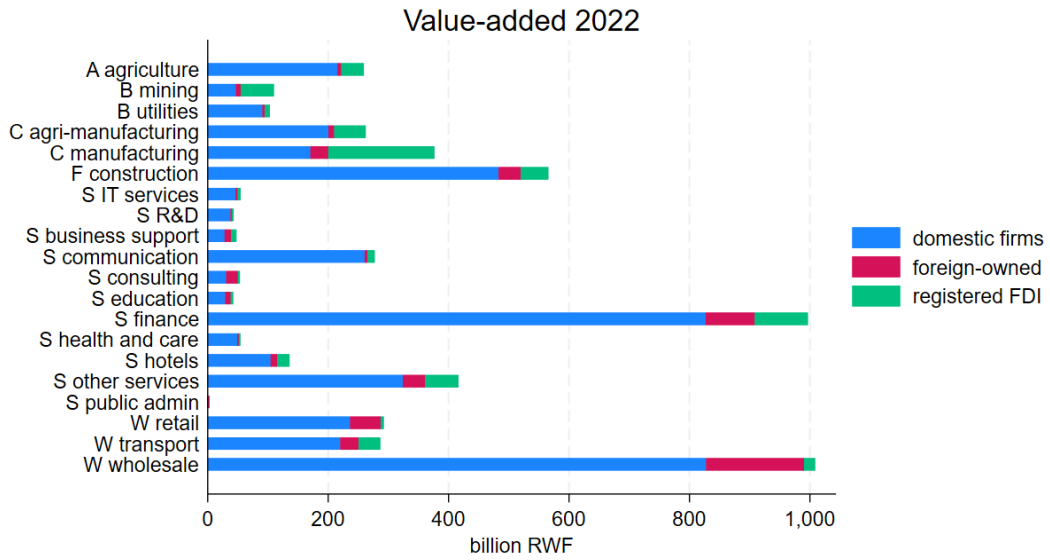
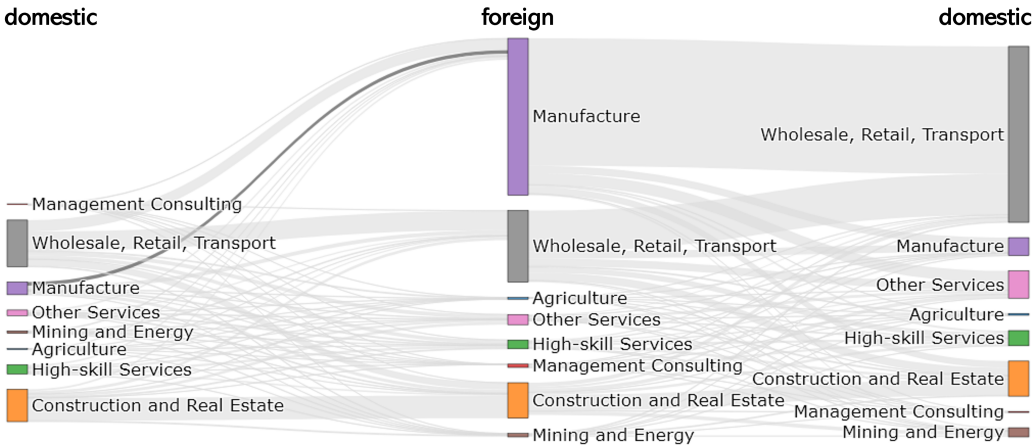


Figure 3 plots the value of firm-to-firm interactions in intermediate inputs by sector during the 2013-2022 period. The leftmost and rightmost panels comprise only domestically owned firms in Rwanda. The central panel covers all foreign-owned firms active within Rwanda. Flows from the left panel to the middle panel represent the sum of business-to-

business sales from domestically owned to foreign-owned firms within Rwanda broken down by economic sector. Flows from the middle to the rightmost panel represent the sum of sales from foreign-owned firms active in Rwanda to domestic firms in Rwanda. All other sales and purchases (final sales to individuals, sales between domestic firms, imports and exports) are omitted from the figure. The interactions most prone to positive spillover effects from FDI through backward-linkages emphasised in the literature are highlighted in a darker shade. Figure 3 makes evident that sales by domestic suppliers of intermediate inputs to foreign manufacturers (backward linkages) account for a very small fraction of interactions between domestic and foreign firms. Especially within the manufacturing sector, a larger fraction of interactions with the domestic economy plays out through forward linkages.[10] Overall, during the observed period the nominal value of forward-linkages is more than twice that of backward linkages, although the share of backward linkages has risen over time.[11]

Figure 3: Aggregate transactions between domestic and foreign firms 2013-2022



4 Forward and Backward Linkages

4.1 Descriptive Analysis

We begin the analysis of spillovers from FDI using two-way fixed-effect (TWFE) regressions. Using the VAT firm-to-firm transactional data, we compute the sales shares between firms from firm i to firm j as $s_{ij,t} = \frac{sales_{ij,t}}{\sum_j sales_{ij,t-1}}$. Note that we use previous year's sales in the denominator. We then define a threshold of 10% in the baseline results and consider a

10. Another indication for the market-seeking behaviour of foreign-owned firms in Rwanda is that out of the 300 foreign firms active in the manufacturing sector, only 30 ever export larger volumes than they import.

11. In 2022, forward linkages amounted to foreign-owned firms selling approximately USD 575 million in goods and services to domestic firms and sourcing approximately USD 350 million from domestic firms. This compares to a nominal GDP of approximately USD 13.3 billion.

domestic firm as exposed to a foreign firm through backward linkages if in a given year at least 10% of its sales scaled by previous year's total sales were directed at a foreign firm i.e.

$$Z_{it}^{\text{backward}} := \text{any}_{j \in \text{foreign}, l \leq t}(\mathbb{1}\{s_{ij,l} \geq \text{threshold}\})$$

We then add a refinement to ensure that first-time exposure is not triggered by marginal increases in sales shares (e.g. from 9.9% pre-treatment to 10.1%) but reflects substantive increases. To this end, we consider a firm as already exposed if its sales shares exceeded the 10% threshold in the following year and the difference in sales shares between the current and following year were below a second threshold (we use 5%).

$$Z_{it}^{backward} = \begin{cases} 1 & \text{if } Z_{it+1}^{backward} == 1 \ \& \ \text{any}_{j \in \text{foreign}}(\mathbb{1}\{(s_{ij,t+1} \geq 0.1) \& (s_{ij,t+1} - s_{ij,t}) < .05\}) \\ Z_{it}^{backward} \end{cases}$$

Similarly, we define the same objects for purchases $b_{ji,t} = \frac{sales_{ji,t}}{\sum_j sales_{ji,t-1}}$ and define exposure to a foreign firm through forward linkages as

$$Z_{it}^{\text{forward}} := \text{any}_{j \in \text{foreign}, l \leq t}(\mathbb{1}\{b_{ji,l} \geq \text{threshold}\})$$

with the refinement

$$Z_{it}^{forward} = \begin{cases} 1 & \text{if } Z_{it+1}^{forward} == 1 \ \& \ \text{any}_{j \in \text{foreign}}(\mathbb{1}\{(b_{ji,t+1} \geq 0.1) \& (b_{ji,t+1} - b_{ji,t}) < .05\}) \\ Z_{it}^{forward} \end{cases}$$

We interpret exposure to a foreign firm to be an absorbing state. This means that once a domestic firm has been exposed to a foreign firm over the observation period, we consider it to be treated for the remainder of our observation period. This view of exposure to foreign firms reflects the notion that interaction with foreign firms yields benefits that go beyond the immediate transactional value from selling or sourcing to the firm but rather imply some persistent effects on the domestic firm. We restrict our sample of analysis to domestic firms in Rwanda. We then estimate the following TWFE specification using OLS.

$$Y_{it} = \beta_0 + \beta_1 Z_{it}^{\text{backward}} + \beta_2 Z_{it}^{\text{forward}} + \beta_3 \mathbf{X}_{it} + \alpha_i + \gamma_t + \varepsilon_{it} \tag{1}$$

where $\mathbf{X_{it}}$ comprises additional controls, α_i and γ_t are firm- and year fixed effects respectively. Figure 1 comprises the result of the regression for log value-added, log number of employees, the log wage bill per employee and log value-added per employee respectively.[12] The first

12. We measure value-added as the difference between business-income and cost-of-goods-sold from the Corporate Income Tax (CIT) data. Employees are formal full-time employees as reported in the PAYE-dataset. The wage bill comprises both direct wages and indirect labour costs via contributions to social security and in-kind remunerations as reported in the PAYE data. Reported zero-employment and value-added is dropped from the analysis.

column is computed on the full sample whereas the latter three requires reducing the sample to those firms paying into the social security system for employees.

This regression provides suggestive evidence about the presence of spillovers through both forward and backward linkages. On average, value added is 30% higher for domestic firms that start interacting with a foreign-owned supplier or customer. Moreover, increases in formal employment and worker remuneration are associated with forward linkages but not with backward linkages. The last column provides some evidence that any increase in value-added produced by domestic firms is not necessarily due to an increase of the scale or the profitability of operations. The increase in value-added per employee rather suggests the presence of efficiency-gains from interacting with FDI.

Table 1: TWFE regression of forward and backward linkages from foreign-owned firms

	log value-added	log employees	log wagebill /employee	log value-added / employee
foreign supplier	0.227***	0.069***	0.064***	0.124***
	(0.029)	(0.022)	(0.018)	(0.034)
foreign buyer	0.178***	-0.007	0.023	0.150**
	(0.056)	(0.046)	(0.032)	(0.066)
observations	31200	18794	18794	17865
firms	6170	3396	3396	3293
treated firms	4102	2384	2384	2312

Firm-and year fixed effects included. We control for number of observed buyers and suppliers in the previous period. Standard-errors (in parentheses) are clustered at firm-level. We exclude always-treated firms from the analysis.
* p<.1 ** p<.05 *** p<.01

The TWFE strategy suffers from two key identification issues. First, the staggered adoption of treatment in our setting implies that the criticism raised by Goodman-Bacon (2021) applies to the TWFE estimator in our setting. This means that the OLS-TWFE estimator includes invalid comparisons between treated units. Second, the TWFE estimator only identifies an interpretable effect if parallel trends can be assumed between those firms that began interacting with foreign-owned companies and all control units that did not do so. Since we are using the full dataset comprising the universe of formal firms in Rwanda and interaction between domestic and foreign firms is a choice made by firms, this is a very strong assumption to make in our present context. Selection, i.e. the correlation between some measurable and not measurable characteristics of domestic firms, may affect the decision to interact with foreign suppliers. This is a well-known issue in the FDI literature. In the rest of this Section we discuss an identification strategy that is grounded on existing work using a similar setting as ours (Alfaro-Urena, Manelici, and Vasquez 2022; Amiti et al. 2024).

In Appendix Figure 9 we report covariate balance statistics for some firm-level outcome variables between domestic firms not exposed to foreign-owned firms via sales transactions and firms that will become either a supplier or buyer to a foreign-owned firm in the next period. Throughout the sample, firms beginning to interact with foreign-owned firms are younger on average than those not beginning an interaction. Most other observed variables of interest remain relatively balanced for those firms beginning to supply to foreign-owned

firms. By contrast, firms supplying to foreign-owned enterprises in Rwanda are smaller, have lower transaction volume and less employees on average than those firms not supplying to foreign-owned firms. This indicates that selection is a bigger problem when considering the effect of backward linkages. Nonetheless, our identification strategy aims to account for selection both when buying from and when supplying to foreign-owned firms so as to be able to compare both effects.

4.2 Identification Strategy

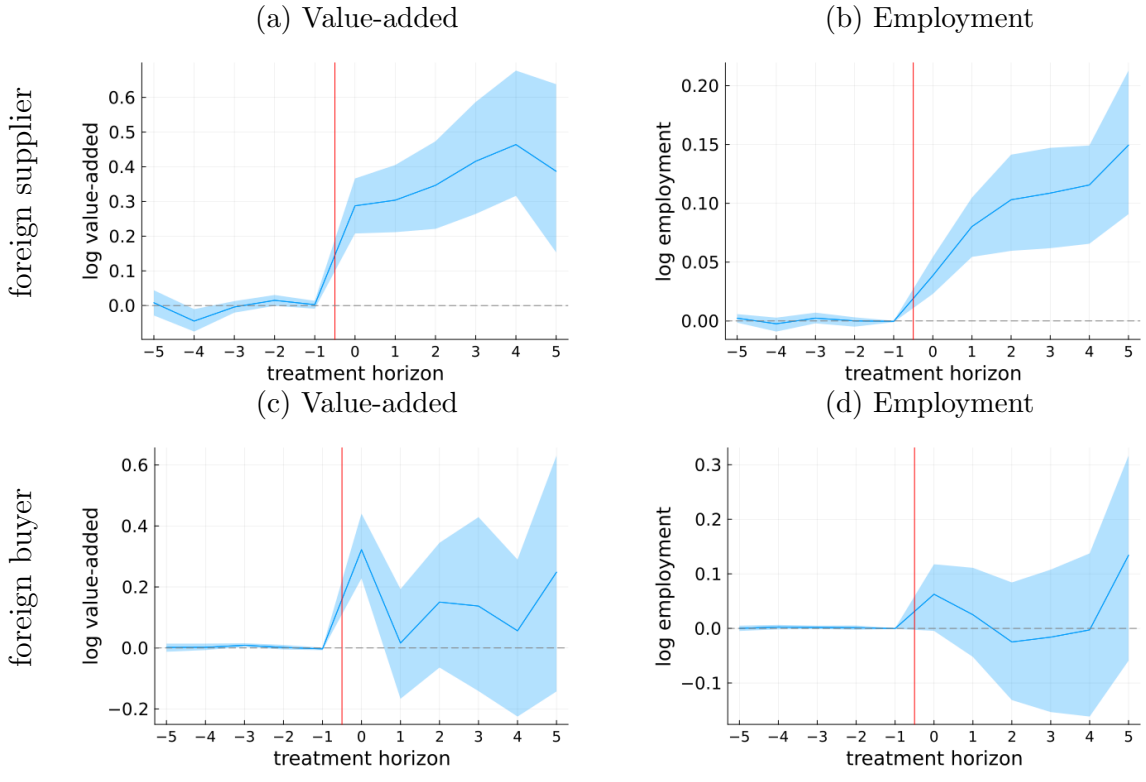
To address the above-mentioned issues, we employ the Synthetic Control Difference-in-Differences approach developed by Arkhangelsky et al. (2021). This approach uses a weighted average of valid control units in such a way that parallel trends between treated and control units hold in the pre-treatment period *by construction*. The identifying assumption is that the synthetic control unit that mirrored the outcome pre-treatment continues to be unbiased for the counterfactual potential outcome of treated units after treatment occurs. This approach effectively yields a data-driven way to select control units from our large pool of possible control units in such a way that the treated firms are best mirrored by these control units. Arkhangelsky and Hirshberg (2023) discuss how the creation of a synthetic control can overcome selection bias present in Difference-in-Difference settings. The use of a synthetic control replaces the parallel trends assumption with the weaker assumption that treatment is independent of the counterfactual potential outcomes when conditioning on permanent unobserved firm-characteristics and the observed pre-treatment information.

Synthetic control group estimators in the literature have been defined only for balanced panels. Since our panel is unbalanced, using this methodology therefore would force us to drop a large number of observations arguably in a non-random fashion. To overcome this issue, we extend the Synthetic Control methodology to be applicable to unbalanced panels without gaps. Appendix C presents formally how this is achieved. We partition our observations of treated units observed at different horizons into cohorts of unit-horizon observations with the maximum number of pre-treatment observations available for this cohort. We then select the control units comprised of never-treated and the valid sample of not-yet-treated units for this cohort that are observed over at least the same time-period. We use this cohort to compute a synthetic-control group and retain the effect of the Synthetic-Control Difference-in-Difference estimator for the treatment horizon under investigation. Finally, we average the horizon-specific effects from different cohorts weighting them by the number of treated units in the cohorts. The retention of only the last horizon for each cohort ensures that no treated unit enters our horizon-specific post-treatment estimates multiple times.

5 Results

The top panel in Figure 4 presents the event-study type point estimates of forward linkages using the unbalanced-panel SCDID estimator for our full sample. Confidence intervals are computed using a clustered studentized bootstrap at the 95% confidence-level with 66 bootstrap iterations. The sample is restricted to those treated firms for which at least 3 pre-treatment observations are available, since the synthetic control method crucially relies on pre-treatment information to compute the synthetic control unit. The estimates lend support to the presence of sizeable and persistent spillover effects on firm-performance through forward linkages. Domestic firms that become customers of foreign firms increase their value-added by 20%-30% following the first sourcing event. This effect decreases over time but remains persistent. Likewise, employment of these firms increases by roughly 10%. This adjustment is strongest the year following the first interaction indicating the presence of persistent changes to firms' operations. Estimates for the wagebill and value-added per employee (reported in the Appendix Figure 10) are less precisely estimated, but they indicate that at least some of this effect is due to improvements in domestic firms' productivity rather than simply an expansion of scale. Both value-added per employee and the average compensation per employee rises significantly by about 5-10% at least in the year of the interaction and the following year.

Figure 4: Synthetic Control Difference in Difference event studies



Evidence for backward linkages, on the other hand, is less clear. The bottom panel of

Figure 4 indicates that in the year where domestic firms sell to a foreign-owned firm their value-added increases by about 30%. However, in the years afterwards, the average effect drops substantially and there is much larger heterogeneity in the trajectory of value-added from then on. The jump in value-added in the year of sales to foreign firms is almost a mechanical result if sales to foreign firms are on average larger in scale than domestic firms' usual operations. Since value-added reverts back to pre-exposure levels quickly, this may imply that backward linkages from FDI in Rwanda do not provide a major channel for productivity spillovers. This view is supported by the other variables analysed. Exposure to foreign firms has no significant effect on firms' employment and employees do not become more productive after their firm sells to foreign-owned firms, except for the same spike in value-added per employee that drives results for overall value-added.

5.1 Robustness Checks

5.1.1 Entry of foreign firms

We analyse exposure to a sub-sample of foreign suppliers that have entered the economy earliest in the year before the exposure is observed. This strategy - employed also in Amiti et al. (2024) - ensures that the option to source from the foreign firm in question was not available in periods prior to treatment such that the ability to begin sourcing can be seen as an exogenous shock to the domestic firm under investigation. Appendix Figure 11 reports the results for beginning to source from a foreign owned firm that has begun its operations in the year or the year before the first observed interaction. The treatment group and control groups are constrained to not have interacted with any other foreign-owned firms prior to treatment and the control group is constrained not to source from foreign-owned firms at all during the period of observation. These restrictions evidently reduce the sample and omit a lot of substantial interactions between foreign and domestic firms observed in the data.[13] Nonetheless, the persistent spike in increased value-added after sourcing from a foreign-owned firm is maintained, although the bootstrap confidence intervals increase due to the substantial reduction in sample size.

5.1.2 Alternative Methods: Propensity Score and Heterogeneous treatment

The Synthetic-Control method we employ has been shown by Arkhangelsky and Hirshberg (2023) to offer some robustness to endogenous selection into treatment. However, their results are asymptotic in the number of pre-treatment periods. Since we have available a large number of firms and a small to moderate number of pre-treatment periods, we

13. The sample restrictions of being exposed to a foreign-owned entrant while not having sourced from foreign-owned firms before and being observed for at least 3 pre-treatment periods implies that when considering value-added we are using an unbalanced panel of 98 domestic firms that are eventually treated, 41 of which are observed for the full duration of 5 post-treatment periods. The control group consists of more than 2800 firms. For employment we are using 128 treated firms.

complement our baseline results by estimating a treatment model. Given the rich network data available to us, we calculate the propensity to enter into a sales- or purchase relationship with a foreign-owned firm based on the full profile of sales interactions. This approach has been developed by Wang (2023) and computes the network of probabilities that any two firms in the network enter into a sales relationship based on the sales and purchase profiles of its neighbours on the network. Some relatively weak assumptions on the underlying network formation process then allow us to compute the joint propensity score to be exposed to any foreign supplier or customer.[14] The propensity score thus estimated is a generalisation of logit-estimation of propensity to be treated if the covariates of the logit-model only include network statistics at the firm-level (and not at the firm-dyad-level). In this sense, it nests the propensity-score based approach in Alfaro-Urena, Manelici, and Vasquez (2022). We follow the approach in Wang (2023) to compute the propensity scores of interaction with any foreign-owned firm and compute Inverse Probability Weighted (IPW) estimates using a TWFE estimator as well as the estimator proposed in Callaway and Sant'Anna (2021). This approach is consistent under the assumption that the propensity score we compute achieves covariate-balance on all relevant (observed or unobserved) confounding variables. Appendix Figure 12 confirms that our method achieves overlap in the propensity score between treated and control units.[15] The results reported in Appendix Figures 13 and 14 are qualitatively similar to our baseline results, although the TWFE estimates do not lead us to confidently rule out the existence of pre-trends leading us to favour our Synthetic-Control-Difference-in-Difference results.

5.1.3 Unique treatment

A potential concern for our analysis is that units in the control group for any of the estimates might be exposed to a different treatment. In Appendix Figure 15 we therefore repeat the analyses for the main outcomes from Figure 4 but restricting the control units to not being exposed to either forward or backward linkages from any foreign firm. For the first two columns, we also exclude observations from both treated and control units that do not appear in the firm-to-firm transaction data such that we ensure the effects observed are not driven by first-time entering into a formal supplier-buyer relationship.[16]

14. The theoretical justification to treat the estimated probabilities of a link between any two firms as independent when calculating propensity scores is based on the theory of the deconfounder (Wang and Blei 2019). The estimated propensity score therefore not only conditions on observed variables, but also on unobserved confounders that are correlated with the process of selecting buyers and suppliers. A key assumption is that any confounding variable affects the potential sales interaction between multiple firms at once and never just a single binary relationship between two firms.

15. Since we employ weighting strategies, we drop units with extreme propensity scores of below 1% and above 99%.

16. Note that for firms selling to foreign-owned firms, this additional restriction decreases sample size beyond acceptable levels since most sellers to foreign-owned firms do source from foreign-owned firms at some point in the observed period.

5.1.4 Alternative definition of FDI

Figure 20 reports the effects of first-time exposure via forward linkages to a firm registering for FDI incentives with the Rwanda Development Board's Onestop Centre. Figure 21 does the same for exposure via backward linkages. The results are largely similar to those using the broader definition of foreign-owned firms used in the main section of the paper.

5.1.5 Alternative thresholds

We also investigate whether our results are robust to variations in the threshold of sales or purchase shares to foreign-owned firms used to define treatment exposure Z_{it}. Appendix Tables 5 and 6 report the same Synthetic-Control Difference-in-Difference estimates as in our baseline configuration in Figure 4 for different thresholds ranging from 1% to 20% of purchases (sales) made with a foreign-owned firm in order to qualify as treated. The results are robust across specifications confirming that the effect is robust to variation in the definition in exposure to foreign-owned firms through sales-interactions.

5.1.6 Misreporting

The change in firm outcomes that we observe in our analysis might be due to a change in their reporting behavior when they start interacting with foreign firms. There is evidence that a significant share of firms make costly reporting errors in low-income countries (Almunia et al. 2024). It is possible that firms improve their reporting standards after engaging with foreign firms, which has a bearing on their VAT disclosures.

To check whether part of our results are affected by reporting behavior, we use the methodology from the tariff evasion literature (Fisman and Wei 2004; Javorcik and Narciso 2008; Beverelli and Ticku 2022). Specifically, we construct a proxy measure of misreporting, which is the difference between seller i's reported sales (s) to domestic buyer j in month-year m (in log) and buyer j's reported purchases (b) from seller i in the same month-year (always in log). We then take the average of the discrepancies across all buyers who report purchases to construct a seller's misreporting measure in a given year:

$$d_{ijm} \;=\; \log\big(s_{ijm}\big) \;-\; \log\big(b_{jim}\big), \tag{2}$$

$$\bar{d}_{it} \;=\; \frac{1}{J_{it}} \sum_{j=1}^{J_{it}} \left(\frac{1}{M_t} \sum_{m \in \mathcal{M}_t} d_{ijm} \right) \tag{3}$$

Appendix Figure 16 shows that the distribution of the misreporting measure ($\bar{d}_{it}$) is skewed to the left, suggesting that firms tend to under-report domestic sales compared to purchases reported by their buyer firms. The result of the synthetic DiD presented in Appendix Figure 17 suggests that firms' reporting behavior does not change around the time

they begin buying from foreign firms. However, Appendix Figure 18 suggests that firms do report higher sales relative to purchases reported by their buyers after they start selling to foreign firms. The effect might be driven by firms, that were formerly underreporting sales to minimize tax payments, disclosing sales truthfully after they start selling to foreign buyers. Appendix Figure 19 plots the cumulative distribution of the discrepancy measure for firms that sell to foreign buyers, before and after treatment. There is a significant drop in the share of firms that under-report sales after they start selling to foreign firms, suggesting an improvement in reporting behavior.

5.2 Forward Linkages by Sector

FDI in Rwanda are spread across a variety of sectors. In the context of forward linkages, it is of interest to analyse the effects of interacting with foreign firms from different industries in some more detail. This may provide some indications regarding the mechanisms at play. There is an important conceptual difference of domestic firms purchasing from foreign manufacturing firms and purchasing from foreign service firms. That is because many services are less tradable internationally than manufacturing goods that can either be purchased from local producers or imported. Nayyar, Hallward-Driemeier, and Davies (2021) analyse the rising role of services in economic development. They emphasise the heterogeneity of services introducing a distinction between skill-intensive and less skill-intensive services. Following Nayyar, Hallward-Driemeier, and Davies (2021)'s classification of skill-intensive services, we therefore investigate the effect of exposure to foreign firms in manufacturing, the skill-intensive service sector,[17] and wholesalers separately. We also include estimates for firms purchasing the services of foreign management consultancies. This is motivated by the notion that improved management practices offer the opportunity of large efficiency gains in developing countries (Bloom et al. 2013).

To separate the effect of sourcing from a domestic firms from the effect of sourcing from a foreign-owned firm in a sector, we control for exposure variables to the domestic sector of interest defined the same way as exposure to foreign firms. Next, we define an indicator variable for exposure to either foreign firms in the sector under investigation, domestic firms in the sector or both and repeat the regression from equation (1) with this new indicator variable. We include controls for backward linkages, as well. We conduct a Wald test for equality of the three coefficients associated with the indicator variable. Rejection of the null hypothesis of equal coefficients implies a significant difference between the forward linkages from exposure to domestic and foreign-owned firms in the sector under investigation. The results for log value-added are presented in Table 2 and those for employment in Table 3. Note that the comparison reported in both tables are constrained to be within the same sector as described in the headings.

17. Skill-intensive services are firms classified under sections M (professional, scientific and technical activities), J (Information and communication), or P (education) of the ISIC rev.4 classification.

The results confirm that exposure to foreign firms is associated with higher levels of value-added and employment. The positive coefficient of exposure to domestic firms active in the same sectors indicates that a part of the effect is due to the composition of goods and services offered by foreign firms and not only due to superior quality of these inputs. However, the significant Wald tests point towards some differences in the extent to which sourcing from foreign firms provides superior benefits than sourcing from domestic firms. This is visible particularly in the service sector and for wholesale firms that import capital goods or precessed intermediate inputs where the Wald test consistently and strongly rejects equality of coefficients for both value-added and employment. Interestingly, the positive effect of sourcing from foreign-owned wholesalers only arises for those wholesalers engaged in the importation of capital goods and processed inputs, highlighting that for interaction with wholesalers the import channel seems to play an important role driving the effects of forward linkages with foreign-owned firms.

Table 2: TWFE of forward and backward linkages: log value-added

	manufacture	service	skill-intensive service	consulting	wholesale	capital importing wholesale	input importing wholesale
domestic supplier	0.160***	0.202***	0.179***	0.221***	0.097**	0.051	0.147***
	(0.031)	(0.034)	(0.037)	(0.051)	(0.038)	(0.036)	(0.035)
foreign supplier	0.324***	0.258***	0.175***	0.253***	0.005	0.136**	0.183***
	(0.061)	(0.067)	(0.056)	(0.074)	(0.098)	(0.063)	(0.066)
foreign and and domestic supplier	0.348***	0.442***	0.396***	0.397***	0.276***	0.328***	0.346***
	(0.048)	(0.053)	(0.066)	(0.125)	(0.046)	(0.044)	(0.042)
foreign buyer same sector	0.231***	0.187**	0.261***	0.395**	0.132		
	(0.077)	(0.087)	(0.098)	(0.157)	(0.084)		
Wald test	12.09	13.16	6.56	1.10	20.18	39.02	20.83
p	0.000	0.000	0.001	0.334	0.000	0.000	0.000
observations	41932	42664	43053	45702	34795	37535	37009
firms	8760	8921	9021	9745	7049	7652	7534
treated firms	2051	1316	1070	384	3580	3170	3321
foreign treated	317	316	446	201	65	189	185
both treated	1734	1000	624	183	3515	2981	3136

Controls include overall number of suppliers and customers in the previous year, sourcing from and selling to foreign-owned firms in different sectors, firm-and year fixed effects. Standard-errors (in parentheses) are clustered at firm-level. The Wald-test is for equality of the first three coefficients reported. We exclude always-treated firms for the current sector from the analysis. Treated firm means buying from a foreign-owned firm. Skill-intensive services are firms classified under sections M (professional, scientific and technical activities), J (Information and communication), or P (education) of the ISIC rev.4 classification.

* p<.1 ** p<.05 *** p<.01

Table 3: TWFE of forward and backward linkages: log employment

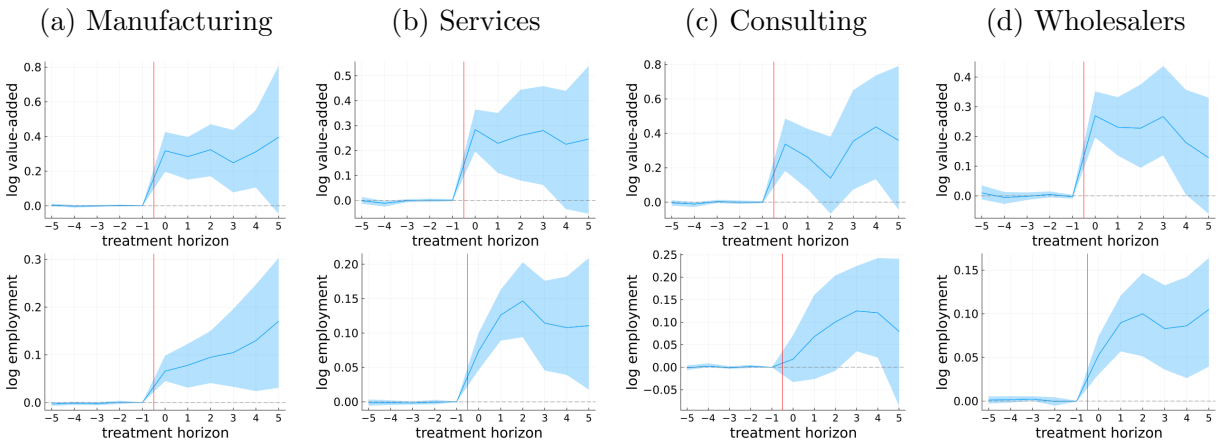
	manufacture	service	high-skill service	consulting	wholesale	capital importing wholesale	input importing wholesale
domestic supplier	0.053**	0.052**	0.033	0.051	0.055*	0.003	0.055**
	(0.022)	(0.026)	(0.026)	(0.033)	(0.029)	(0.027)	(0.026)
foreign supplier	0.131***	0.141***	0.089**	0.077	0.085	0.078*	0.037
	(0.048)	(0.040)	(0.038)	(0.056)	(0.068)	(0.042)	(0.039)
foreign and domestic supplier	0.149***	0.182***	0.101**	0.050	0.116***	0.099***	0.130***
	(0.035)	(0.038)	(0.043)	(0.058)	(0.034)	(0.034)	(0.032)
foreign buyer same sector	0.025	0.023	0.035	0.254*	-0.080		
	(0.068)	(0.067)	(0.078)	(0.151)	(0.068)		
Wald test	5.32	8.29	1.74	0.12	3.42	7.00	5.39
p	0.005	0.000	0.175	0.884	0.033	0.001	0.005
observations	24282	24232	24519	25775	20807	21898	21901
firms	4605	4579	4645	4968	3821	4047	4051
treated firms	1032	954	774	343	2015	1795	1822
foreign treated	151	175	279	178	49	116	108
both treated	881	779	495	165	1966	1679	1714

Controls include overall number of suppliers and customers in the previous year, sourcing from and selling to foreign-owned firms in different sectors, firm-and year fixed effects. Standard-errors (in parentheses) are clustered at firm-level. The Wald-test is for equality of the first three coefficients reported. We exclude always-treated firms for the current sector from the analysis. Treated firm means buying from a foreign-owned firm. Skill-intensive services are firms classified under sections M (professional, scientific and technical activities), J (Information and communication), or P (education) of the ISIC rev.4 classification.

* p<.1 ** p<.05 *** p<.01

We complement the TWFE regression results with synthetic control event-studies of sourcing from firms in manufacturing, services, and consulting specifically. Figure 5 presents

Figure 5: Forward linkages from exposure to foreign firms by sector



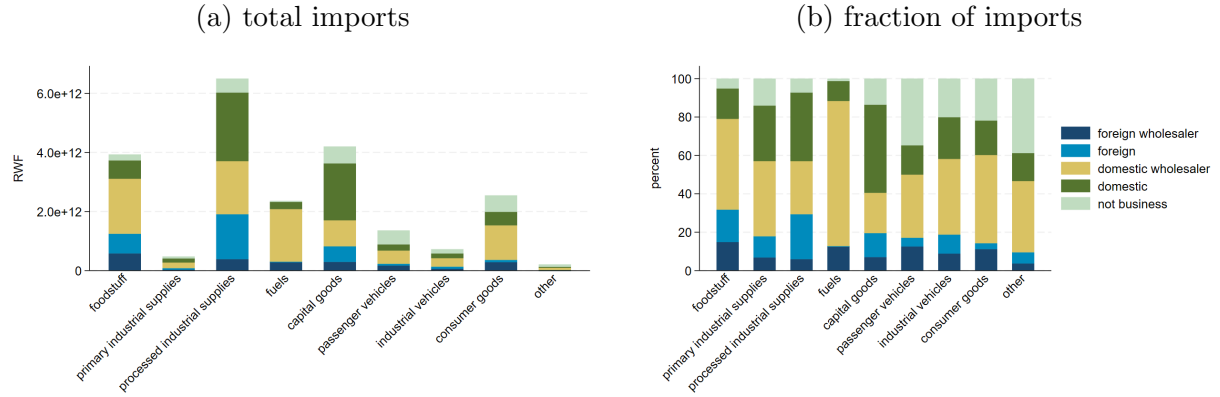
the results for sourcing from foreign-owned firms in manufacturing, services and after purchasing management consulting services with 95% bootstrap confidence intervals for exposure to foreign firms. The results indicate the presence of forward linkages in both services and manufacturing.

6 Mechanisms

6.1 Quality of intermediate inputs

In this section we provide suggestive evidence for the transmission mechanisms governing the positive spillover effects for domestic firms sourcing from foreign-owned companies. Figure 6 summarises the fraction of Rwanda's imports conducted by foreign-owned firms. Especially within the categories of food products and industrial intermediate inputs - both primary and processed - foreign-owned firms account for a sizeable share of overall imports to Rwanda.

Figure 6: Fraction of imports by foreign-owned firms



One possible channel through which sourcing from foreign-owned firms may increase

domestic firms' economic performance is that foreign-owned firms provide intermediate input goods of higher quality than domestic firms can offer. Part of this effect may come from access to intermediate inputs imported from abroad and would be reflected in detailed customs data on imports conducted by foreign-owned firms. To get a sense of quality differences in the imports of domestic and foreign-owned firms, we analyse import-prices of all importing firms between 2014 and 2022. Within each category of 8-digit HS-codes of imports, we standardise prices for each 8-digit HS-category of imports each month across all importers. We then regress these standardised prices on the identity of the importer. Table 4 presents the results where imports by domestic firms are the baseline. Some regressions control for a slope of import-quantity in order to capture discounts for large-scale importers. Columns 1 through 4 report regressions on all monthly standardised import prices. Columns 5 through 8 instead compute the mean standardised prices for firms within HS-8 categories such that frequent importers do not appear in the data at a higher rate than infrequent importers. Columns 2, 4 and 6 report the regressions only for imports of industrial inputs as defined by the United Nations Classification by Broad Economic Categories (BEC).

Table 4: Regressions of standardised import-prices on importer type

	firm-month level				firm level			
	all	all	industrial	industrial	all	all	industrial	industrial
foreign	0.048**	0.073***	0.030	0.059**	0.050***	0.088***	0.037**	0.069***
	(0.022)	(0.021)	(0.026)	(0.023)	(0.014)	(0.014)	(0.015)	(0.014)
individual	-0.035*	-0.011	-0.070***	-0.045**	-0.049***	-0.017	-0.083***	-0.057***
	(0.021)	(0.019)	(0.025)	(0.022)	(0.013)	(0.012)	(0.014)	(0.013)
quantity controls	no	yes	no	yes	no	yes	no	yes
observations	2093951	2093943	1006702	1006698	880038	880030	428968	428964
firms	76112	76112	35658	35658	76112	76112	35658	35658

Standard-errors (in parentheses) are clustered at firm-level. The baseline are domestic firms. Quantity controls means that the regression controls for 8-digit HS-code specific slopes with respect to quantity of goods imported by the firm. Columns 1 to 4 regress on standardised import-prices at the firm-month level (computing import prices at the firm-month-HS-code level and then standardising at the month-HS-code level). Columns 6 to 8 regress on standardised import-prices at the firm-level. Columns 1, 2, 5, and 6 report results for all imports. Columns 3, 4, 7, and 8 report results for standardised import-prices only for industrial input goods according to the BEC (Broad Economic Categories), restricting the analysis to BEC categories 21 (Industrial supplies nes, primary), 22 (Industrial supplies nes, processed), 41 (Capital goods (except transport equipment)), and 42 (Parts and accessories of capital goods (except transport equipment)).

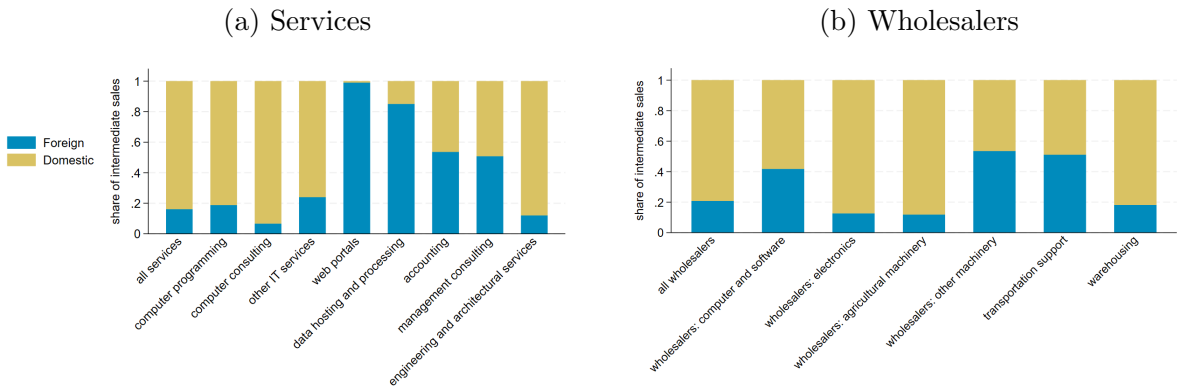
* p<.1 ** p<.05 *** p<.01

Overall, these results suggest that foreign-owned firms import goods at higher unit-prices than domestic firms. This finding is particularly salient when controlling for imported quantities - a measure that may account for quantity discounts. The relatively higher price of imports amounts to 0.05 and 0.09 standard deviations of within-month import prices of the same 8-digit HS category of goods. For imports of industrial inputs the import price difference for foreign-owned firms is slightly less pronounced.

6.2 Sectoral composition and input availability

Foreign firms may offer intermediate inputs that are not provided by any or a sufficient amount of domestic firms. This is particularly salient for sub-sectors of services, which are

Figure 7: Foreign firms' sales shares of intermediate inputs



Note: Intermediate sales are all business-to-business transactions to other firms recorded by firms within the sector during the period 2013-2022 and normalised to 1. All services comprises firms in ISIC Rev.4 sections G through S. All wholesalers are divisions 45 and 46. The fine-grained sectors are ISIC classes: Computer programming (6201), consulting (6202), other IT services (6209), web portals (6312), data hosting and processing (6311), accounting (6920), management consulting (7020), engineering and architectural services (7110), wholesalers for computers (4651), electronics (4652), agricultural machinery (4653) and other machinery (4659), transportation support (5229), and warehousing (5210).

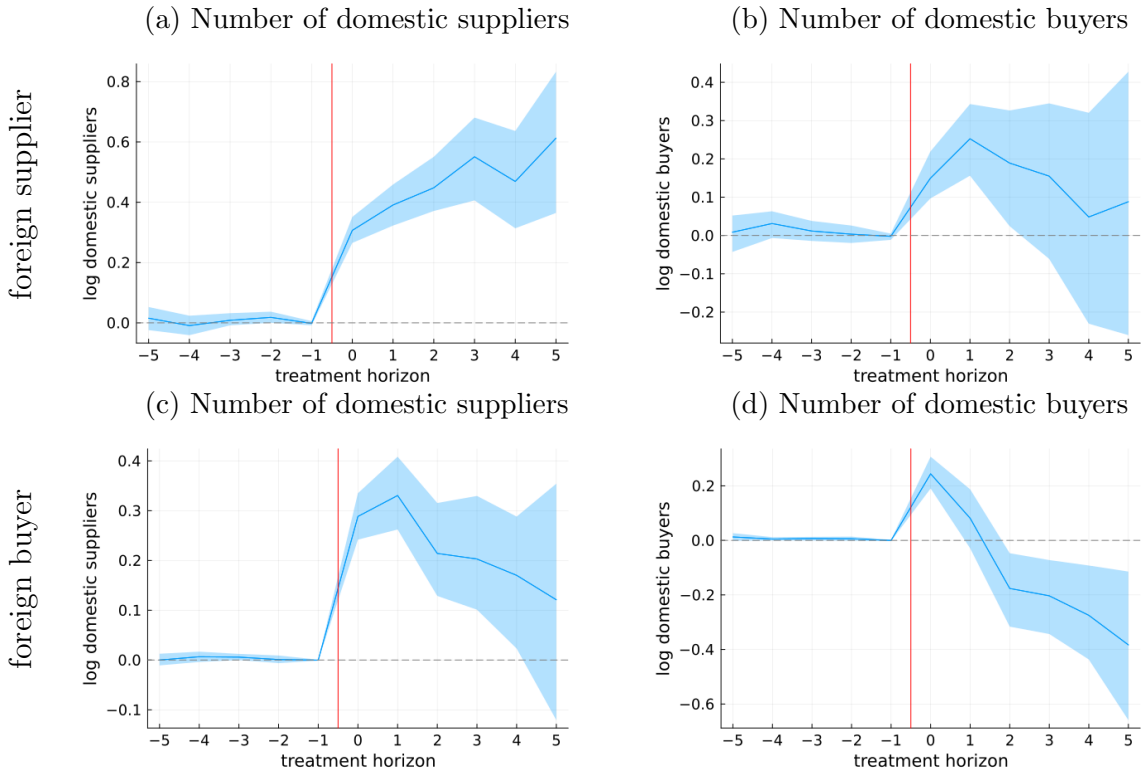
much more difficult to import than physical goods and are typically demanded within a local economy. This is either because a certain service cannot be supplied from afar or because it requires contextual knowledge of local laws and customs (as is the case for accounting and consulting activities). Figure 7 plots foreign firms' business-to-business sales shares within a selection of skill-intensive services at the 4-digit ISIC classification. Intermediate sales by foreign firms of some services such as computer programming and other IT related services are not more concentrated than services overall. In others such as data hosting capacities and the operation of web portals is almost entirely dominated by foreign-owned companies and foreign-owned firms have very large market shares in accounting and management consulting. This suggests foreign firms provide certain types of services to the local economy that either cannot be supplied by domestic firms or that domestic firms cannot supply at the same level of quality or sufficient quantity to satisfy demand. When local firms gain access to such services by purchasing from foreign-owned firms, the resulting productivity gains may help explain the forward linkages observed in our baseline findings.

Similarly, for wholesalers and transport-related services, some specialised distribution activities such as provision of machinery and equipment and logistical support services remain strongly dominated by foreign-owned firms, again suggesting that purchasing from foreign firms gives domestic firms access to types of products that are not offered by domestic competitors.

6.3 Complementarity with domestic suppliers and customers

We provide further suggestive evidence that on average foreign firms do not crowd out domestic suppliers but rather provide complementary inputs for domestic firms. The top panel of Figure 8 depicts the change in the (log) number of domestic suppliers and customers after first sourcing from a foreign-owned firm - i.e. a forward linkage. The results suggest that interaction with a foreign supplier is also associated with an increase in sourcing from a larger number of domestic suppliers. This suggests that foreign enterprises provide inputs to the Rwandan economy that are complementary in production to domestic inputs. The number of domestic customers also increases following a forward linkage with foreign-owned firms.

Figure 8: Synthetic Control Difference in Difference event studies



By contrast, sub-figure d) in the bottom panel of figure 8 suggests that in the medium to long term, selling to a foreign-firm via backward linkages crowds out sales to domestic firms. Following a brief increase up to the year after the first sales interaction with a foreign firm through backward linkages, the number of domestic customers is permanently reduced. This finding is in contrast to dynamics surrounding domestic sales interactions found by Alfaro-Urena, Manelici, and Vasquez (2022) and suggests that in the context of Rwanda interactions with foreign-owned customers are subject to capacity constraints crowding out sales to previously existing domestic customers. This concurs with findings for Tanzanian and Ethiopian manufacturing firms by Diao et al. (2025) that productive suppliers face constraints to expand their scale of operations. At the same time, selling to foreign-owned

firms is associated with an increase in domestic suppliers.

7 Conclusion

We find sizeable and persistent positive spillover effects on Rwandan enterprises from the entry of foreign-owned firms. Consistent with the expectation that the type of FDI spillovers in a small, poor, landlocked economy are less likely to be associated with export-oriented FDI, we find that these effects are stronger and more prevalent for firms interacting with foreign-owned businesses through forward linkages. Spillovers through forward linkages are due to interactions with foreign firms operating in both manufacturing or service sectors, as well as positive effects of beginning to source from domestic firms in the same sector. As predicted by the literature on trade in services, FDI in services is a channel for domestic firms to obtain higher quality services inputs than are available from domestic enterprises. Purchases of professional and business services from foreign-owned firms (management consultancies) have pronounced positive effects on domestic firms value-added and employment.

Our methodology is limited by the focus on the formal economy of Rwanda. Particularly for employment, this caveat implies that for employment outcomes we limit attention to the small subset of firms that contributes to the social security system in Rwanda. One potential way to overcome this issue is to use the Labour Force Surveys in conjunction with information on the geographic location of firms to compute local multipliers of FDI entry proposed by Moretti (2010) not only using the location of foreign-owned firms but also the location of their suppliers and customers. Although a large amount of investment is concentrated in Kigali, this might yield further insights especially for estimates in regions outside the capital.

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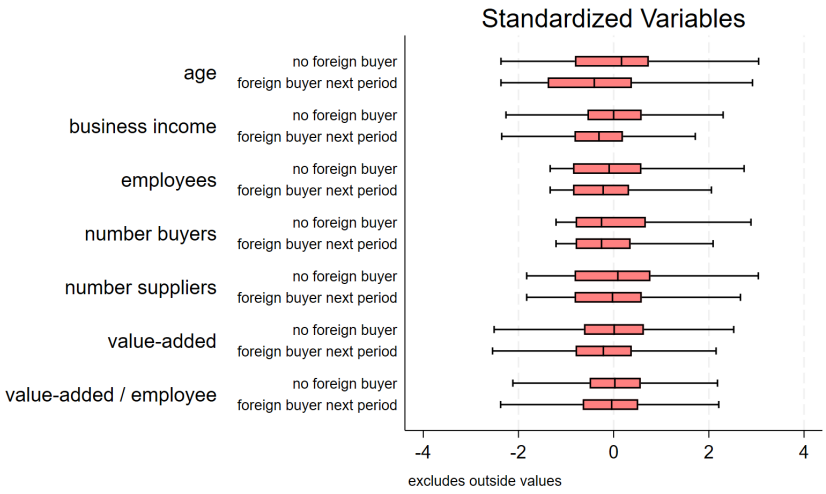
A Additional Results

A.1 Covariate balance statistics

Figure 9: Box plots of firm-level outcome statistics between firms not directly interacting with foreign-owned firms and those that will interact in the next period

(a) Forward linkages

(b) Backward linkages

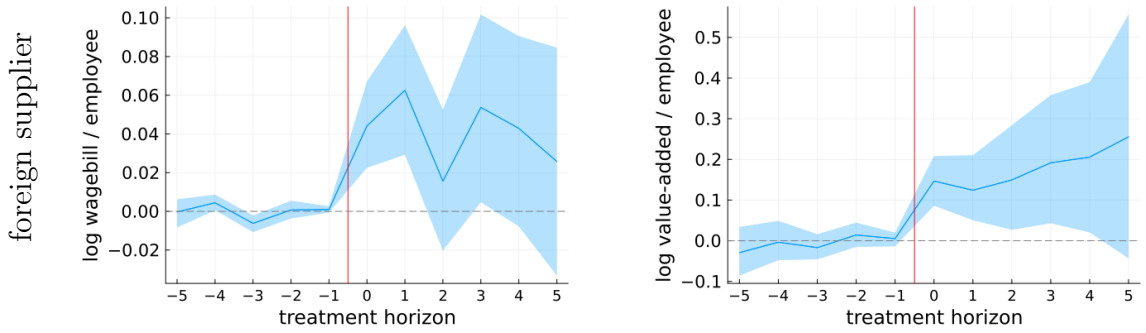


A.2 Synthetic Difference-in-difference estimates for per-employee variables

Figure 10: Synthetic Control Difference-in-Difference event studies

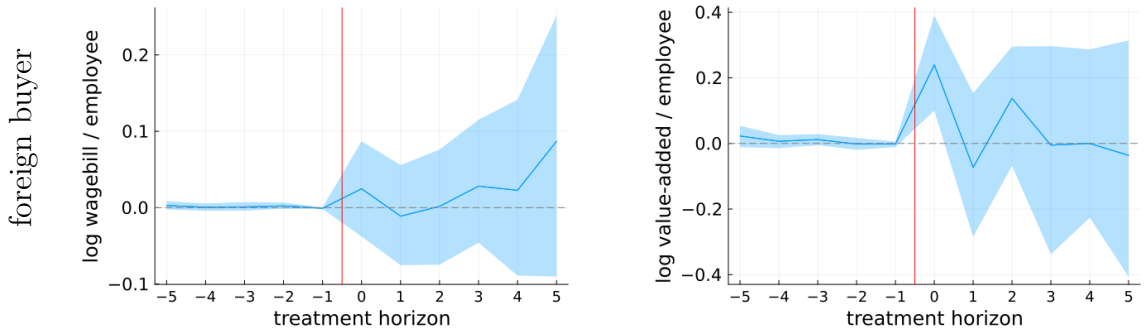
(a) Wagebill per employee

(b) Value-added per employee



(c) Wagebill per employee

(d) Value-added per employee



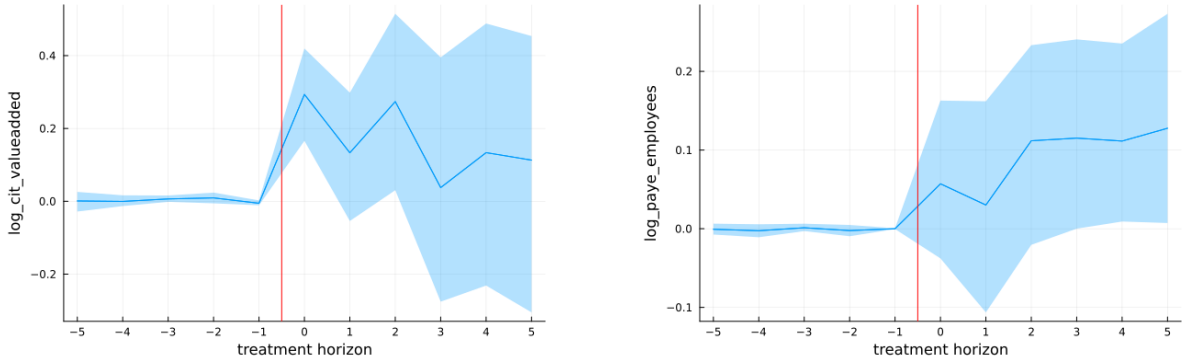
B Robustness checks

B.1 Exposure to foreign entrants

Figure 11: Synthetic control event studies of forward linkages to new entrants

(a) Value-added

(b) Employment

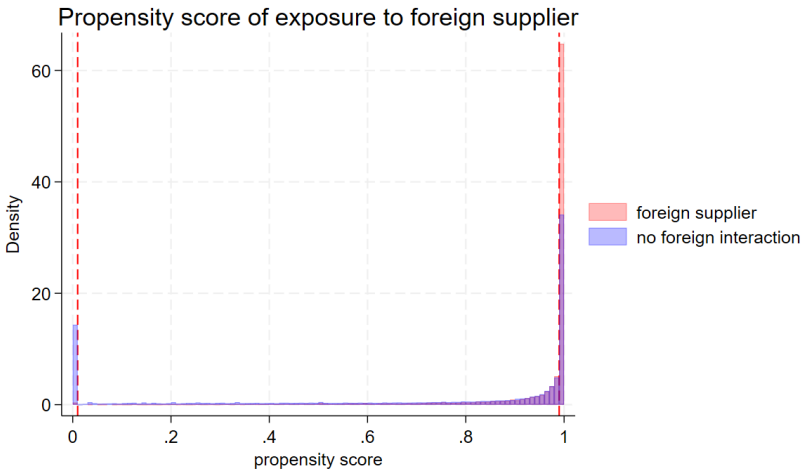


B.2 Alternative specification using network-based propensity score

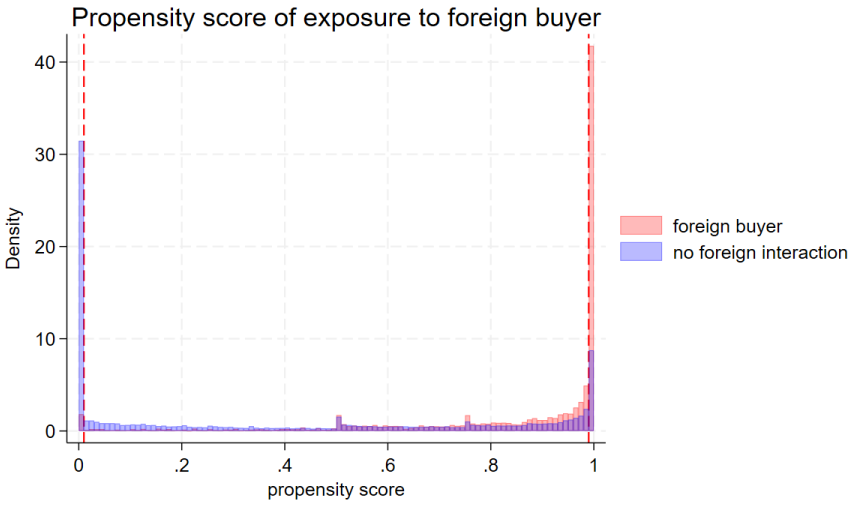
Figure 12 shows the overlap of the network-based propensity score. We apply cut-offs to the propensity score at 0.99 and 0.01 to avoid very extreme weights in the IPS procedure and limit our analysis to firms within this overlap region.

Figure 12: Overlap graphs for the two propensity scores

(a) exposure to foreign suppliers



(b) exposure to foreign buyers



Figures 13 and 14 show figures for standard OLS event-studies, weighted least squares event studies applying inverse probability weights for the ATT using the network-based propensity score to the control units, and Callaway and Sant'Anna event study plots applying the same propensity weighting strategy.

Figure 13: Event studies after exposure to foreign supplier

(a) OLS

(b) IPW

(c) Callaway & Sant'Anna IPW

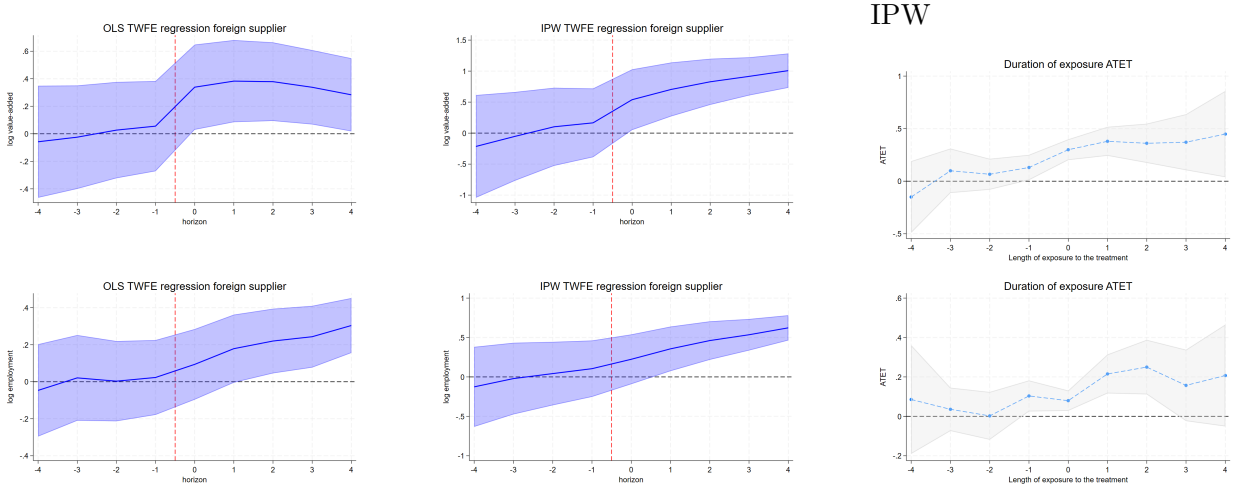
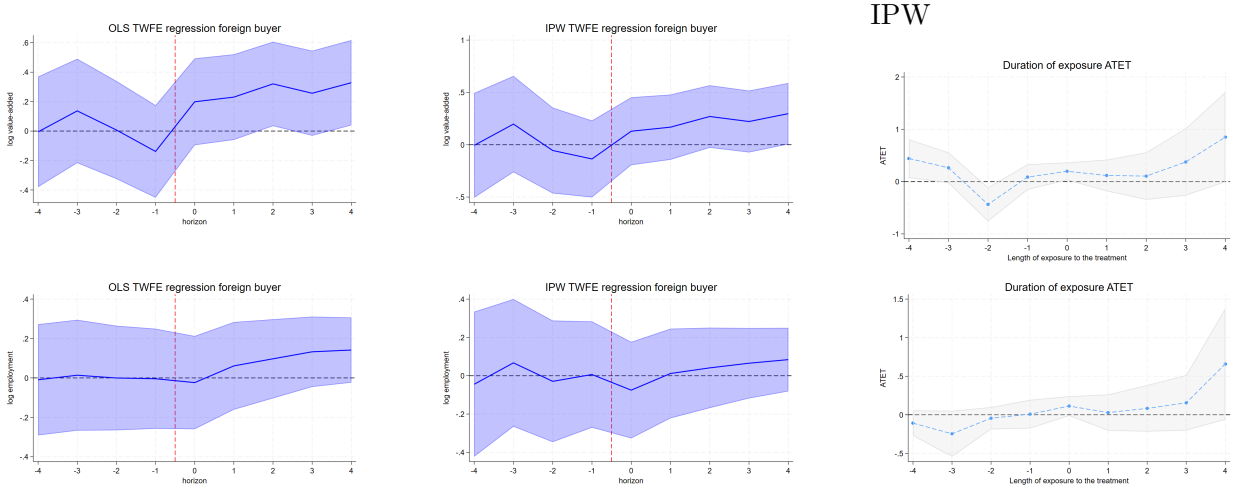


Figure 14: Event studies after exposure to foreign buyer

(a) OLS

(b) IPW

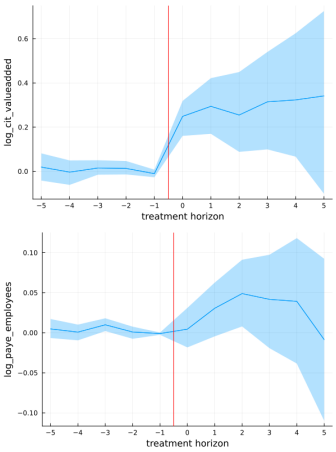
(c) Callaway & Sant'Anna IPW



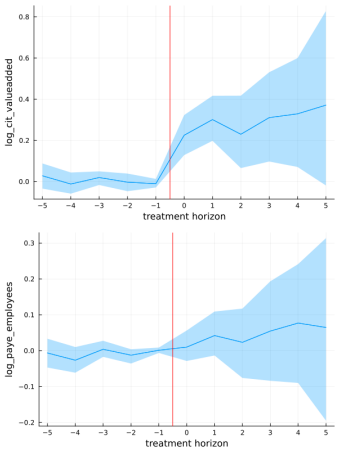
B.3 Alternative treatment and control groups

Figure 15: Forward and backward linkages with restricted control group

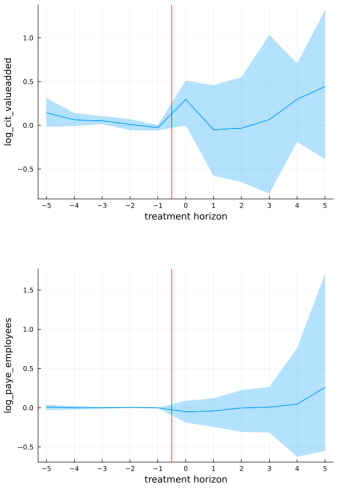
(a) Foreign supplier but no foreign buyer; with positive in-degrees



(b) Foreign supplier but no foreign buyer; with positive in-degrees and out-degrees



(c) Foreign buyer but no foreign supplier



B.4 Misreporting

Figure 16 plots the distribution of misreporting in sales reported by firms over time. The distribution is slightly skewed to the left, implying that firms tend to under-report sales relative to corresponding purchases reported by the buyers. Figure 17 presents results from a synthetic DD estimation which suggests that firms do not misreport sales relative to purchases reported by their buyers around the time they start buying from foreign firms. However, Figure 18 suggests that firms do over-report sales relative to purchases when they begin selling to foreign firms. Figure 19 shows that there is a substantial drop in firms under-reporting sales after they start selling to foreign firms. The drop is comparatively less for firms after they start buying from foreign firms.

Figure 16: Discrepancies in domestic sales

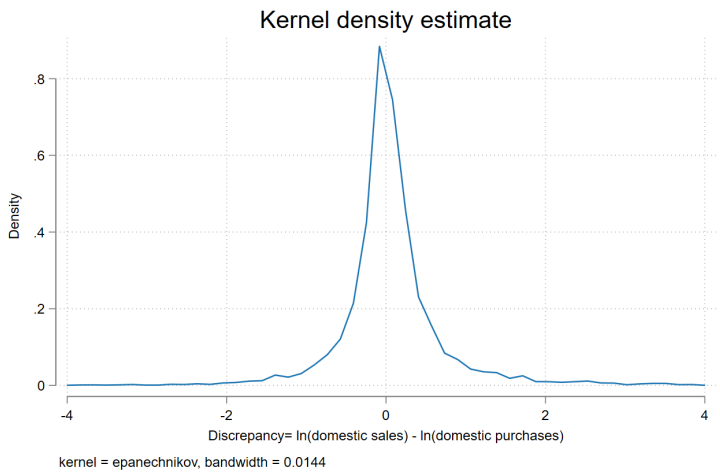


Figure 17: Linkages with foreign suppliers and misreporting

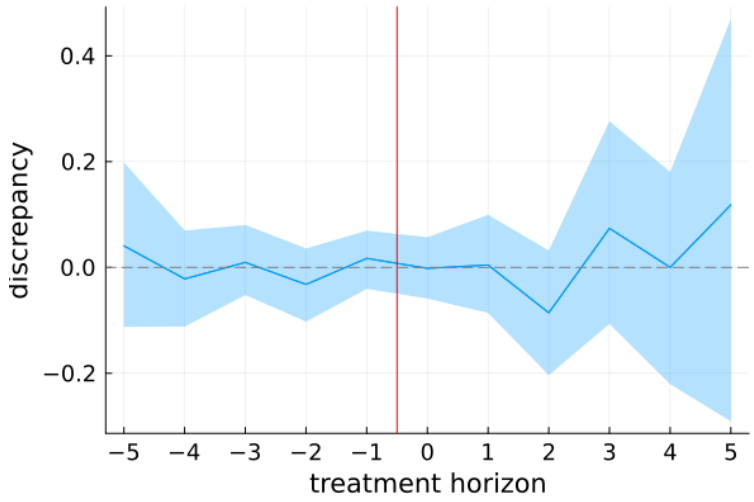


Figure 18: Linkages with foreign buyers and misreporting

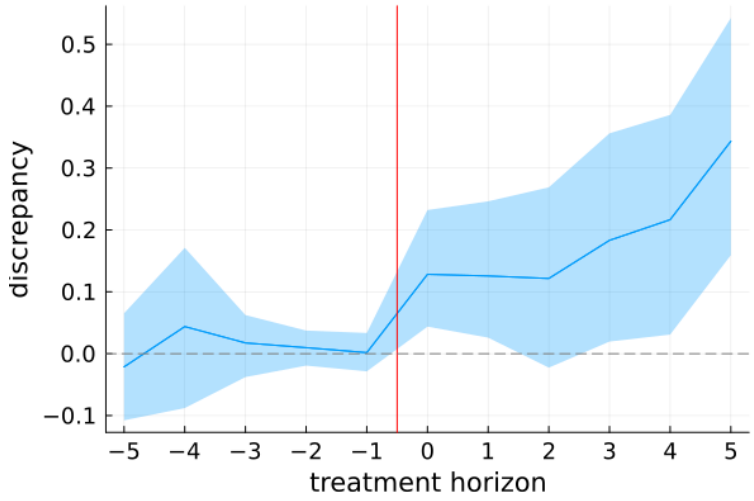
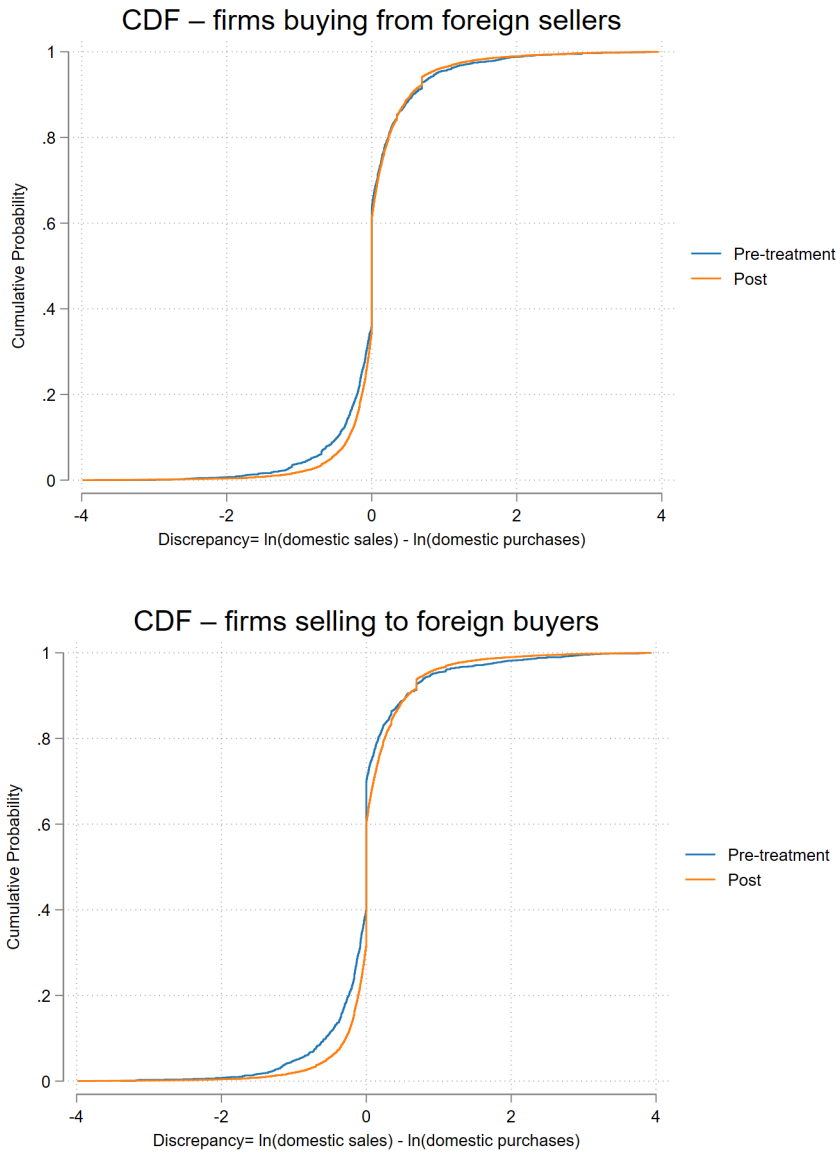


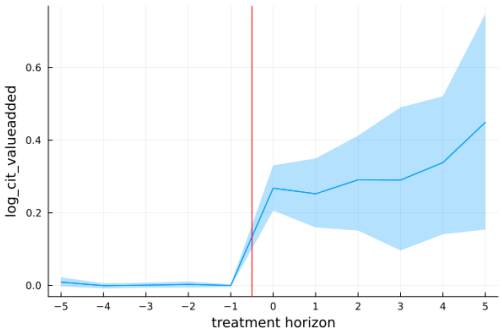
Figure 19: Sales misreporting before and after firms link with foreign firms



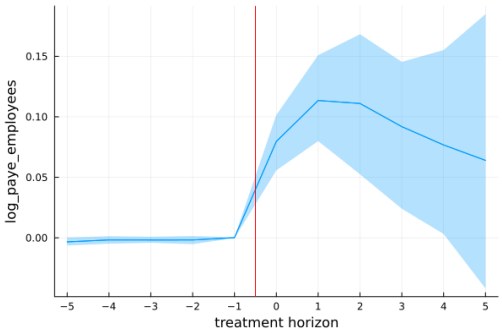
B.5 Alternative definition of FDI

Figure 20: Synthetic control event studies of forward linkages with registered FDI firms

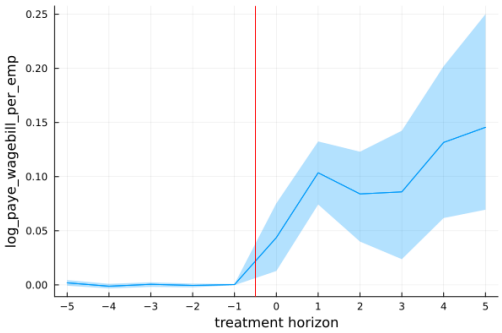
(a) Value-added



(b) Employment



(c) Wagebill per employee



(d) Value-added per employee

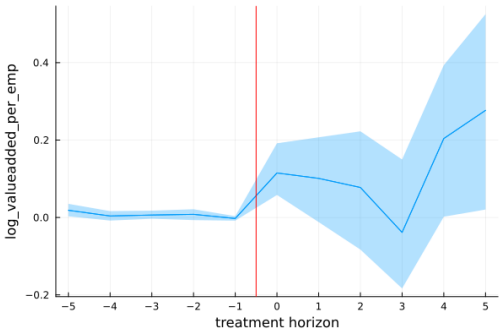
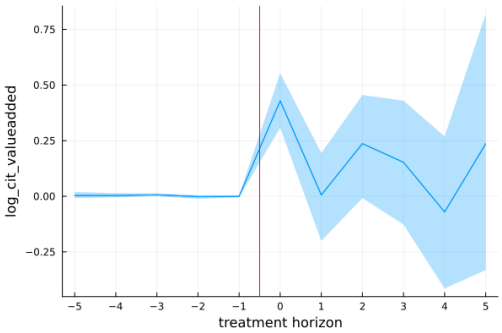
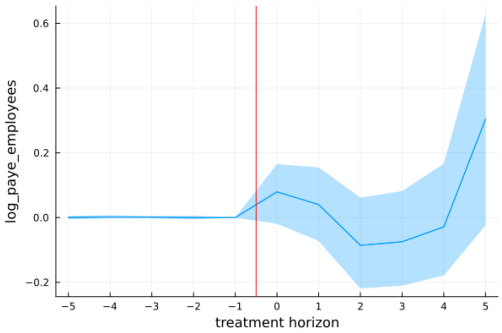


Figure 21: Synthetic control event studies of backward linkages with registered FDI firms

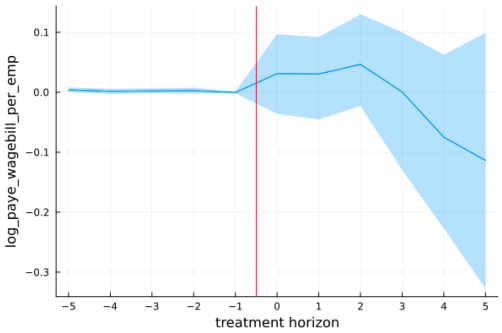
(a) Value-added



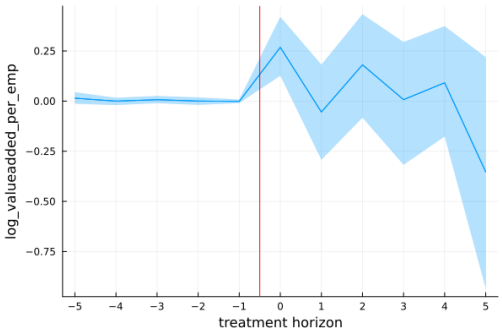
(b) Employment



(c) Wagebill per employee



(d) Value-added per employee



B.6 Alternative exposure thresholds

Table 5: Alternative thresholds: Foreign supplier

	log value-added				log employment			
	1%	**5%**	**10%**	**20%**	**1%**	**5%**	**10%**	**20%**
Horizon								
-5	-0.056	-0.024	0.008	0.019	-0.01	0.002	0.002	-0.001
	(-0.157, 0.048)	(-0.085, 0.023)	(-0.022, 0.035)	(-0.002, 0.046)	(-0.022, 0.0)	(-0.008, 0.011)	(-0.004, 0.009)	(-0.007, 0.005)
-4	-0.094	-0.073	-0.045	-0.015	-0.01	-0.004	-0.002	-0.001
	(-0.153, -0.039)	(-0.112, -0.041)	(-0.075, -0.012)	(-0.036, 0.005)	(-0.021, -0.002)	(-0.012, 0.004)	(-0.01, 0.005)	(-0.006, 0.004)
-3	-0.03	-0.009	-0.004	0.0	-0.003	0.002	0.002	0.001
	(-0.07, 0.014)	(-0.038, 0.024)	(-0.025, 0.018)	(-0.012, 0.016)	(-0.01, 0.005)	(-0.004, 0.009)	(-0.003, 0.008)	(-0.004, 0.005)
-2	0.022	0.01	0.015	0.012	-0.0	0.001	0.0	-0.0
	(0.005, 0.047)	(-0.019, 0.034)	(-0.004, 0.034)	(-0.005, 0.025)	(-0.009, 0.009)	(-0.007, 0.009)	(-0.006, 0.006)	(-0.005, 0.005)
-1	0.027	0.007	0.003	-0.002	0.0	-0.0	-0.0	0.0
	(-0.004, 0.059)	(-0.006, 0.027)	(-0.013, 0.018)	(-0.011, 0.006)	(-0.001, 0.002)	(-0.001, 0.001)	(-0.001, 0.0)	(-0.0, 0.0)
0	0.272	0.265	0.288	0.29	0.055	0.047	0.038	0.05
	(0.203, 0.354)	(0.208, 0.331)	(0.21, 0.36)	(0.216, 0.368)	(0.031, 0.08)	(0.025, 0.069)	(0.02, 0.057)	(0.029, 0.074)
1	0.275	0.287	0.304	0.285	0.104	0.101	0.08	0.092
	(0.169, 0.394)	(0.184, 0.392)	(0.221, 0.387)	(0.204, 0.362)	(0.068, 0.142)	(0.071, 0.134)	(0.049, 0.113)	(0.062, 0.125)
2	0.398	0.374	0.347	0.299	0.128	0.13	0.103	0.133
	(0.258, 0.545)	(0.26, 0.502)	(0.23, 0.434)	(0.193, 0.425)	(0.08, 0.174)	(0.092, 0.166)	(0.069, 0.14)	(0.094, 0.171)
3	0.475	0.442	0.416	0.279	0.145	0.142	0.108	0.143
	(0.263, 0.677)	(0.253, 0.656)	(0.263, 0.558)	(0.141, 0.394)	(0.09, 0.207)	(0.088, 0.194)	(0.063, 0.155)	(0.089, 0.195)
4	0.703	0.574	0.464	0.248	0.175	0.146	0.116	0.132
	(0.45, 0.918)	(0.337, 0.805)	(0.264, 0.648)	(0.04, 0.465)	(0.114, 0.226)	(0.096, 0.199)	(0.062, 0.168)	(0.071, 0.179)
5	0.703	0.56	0.387	0.284	0.23	0.171	0.149	0.175
	(0.344, 1.015)	(0.202, 0.906)	(0.137, 0.637)	(0.064, 0.503)	(0.144, 0.315)	(0.096, 0.255)	(0.093, 0.214)	(0.106, 0.246)

Synthetic Difference-in-difference event-studies for different specifications of the threshold. 95% bootstrap confidence intervals are reported in parentheses.

Table 6: Alternative thresholds: Foreign buyer

	log value-added				log employment			
	1%	**5%**	**10%**	**20%**	**1%**	**5%**	**10%**	**20%**
Horizon								
-5	-0.009	0.001	0.002	0.007	-0.001	0.002	0.0	0.001
	(-0.027, 0.009)	(-0.008, 0.012)	(-0.009, 0.017)	(-0.006, 0.023)	(-0.007, 0.005)	(-0.002, 0.005)	(-0.005, 0.006)	(-0.004, 0.007)
-4	0.005	0.001	0.002	0.004	-0.002	0.002	0.002	0.002
	(-0.006, 0.016)	(-0.009, 0.012)	(-0.007, 0.01)	(-0.003, 0.014)	(-0.006, 0.002)	(-0.001, 0.005)	(-0.002, 0.007)	(-0.003, 0.005)
-3	-0.002	0.01	0.009	0.004	0.002	0.002	0.002	0.001
	(-0.012, 0.007)	(0.002, 0.019)	(0.002, 0.017)	(-0.002, 0.012)	(-0.0, 0.005)	(0.0, 0.004)	(-0.001, 0.005)	(-0.003, 0.004)
-2	0.009	0.002	0.002	0.005	-0.001	0.002	0.001	-0.001
	(-0.0, 0.018)	(-0.004, 0.01)	(-0.006, 0.01)	(-0.003, 0.014)	(-0.006, 0.003)	(-0.002, 0.005)	(-0.002, 0.006)	(-0.005, 0.004)
-1	-0.004	-0.003	-0.003	-0.005	0.0	-0.0	-0.0	-0.0
	(-0.009, 0.002)	(-0.007, -0.0)	(-0.008, 0.001)	(-0.01, -0.001)	(-0.0, 0.0)	(-0.001, 0.0)	(-0.001, 0.0)	(-0.0, 0.0)
0	0.182	0.228	0.322	0.427	0.052	0.066	0.063	0.099
	(0.115, 0.224)	(0.14, 0.314)	(0.232, 0.42)	(0.293, 0.551)	(0.019, 0.078)	(0.014, 0.118)	(0.006, 0.125)	(0.024, 0.179)
1	0.108	0.08	0.016	0.078	0.062	0.039	0.025	0.054
	(0.007, 0.197)	(-0.026, 0.216)	(-0.118, 0.142)	(-0.111, 0.286)	(0.006, 0.118)	(-0.03, 0.105)	(-0.058, 0.115)	(-0.038, 0.156)
2	0.142	0.122	0.15	0.3	0.039	0.028	-0.024	0.07
	(0.025, 0.254)	(0.002, 0.252)	(-0.004, 0.31)	(0.027, 0.55)	(-0.036, 0.117)	(-0.05, 0.114)	(-0.147, 0.102)	(-0.045, 0.184)
3	0.127	0.153	0.137	0.233	-0.022	-0.004	-0.014	0.038
	(-0.023, 0.272)	(-0.029, 0.344)	(-0.097, 0.37)	(-0.08, 0.518)	(-0.091, 0.054)	(-0.108, 0.117)	(-0.155, 0.119)	(-0.046, 0.146)
4	0.093	0.063	0.056	0.153	-0.058	0.035	-0.001	0.012
	(-0.116, 0.298)	(-0.121, 0.297)	(-0.191, 0.311)	(-0.21, 0.429)	(-0.16, 0.036)	(-0.089, 0.168)	(-0.177, 0.169)	(-0.137, 0.157)
5	0.032	0.132	0.248	0.116	-0.084	0.032	0.134	0.257
	(-0.231, 0.297)	(-0.07, 0.365)	(-0.114, 0.528)	(-0.349, 0.592)	(-0.211, 0.04)	(-0.134, 0.186)	(-0.054, 0.349)	(0.036, 0.493)

Synthetic Difference-in-difference event-studies for different specifications of the threshold. 95% bootstrap confidence intervals are reported in parentheses.

C Unbalanced Synthetic Control DiD estimator

In this appendix we outline how we compute the synthetic difference-in-difference estimates for the unbalanced panel. Denote outcomes as $Y_{i,t}$. For any cohort, suppose that we order outcomes such that index $i = 1, ..., N^{co}$ denotes control units. We define a cohort as all units treated at time z, observed at treatment horizon h for which at least p pre-treatment outcomes are observed. That is, a cohort is a sub-panel for which observations are non-missing from period $z - p$ up to period $z + h$. For each cohort (z, h, p) of treated units, we find the cohort of valid controls, that is firms with non-missing observations from $z - p$ to $z + h$ that have not been exposed to treatment at $z + h$. This control group comprises both never-treated and not-yet-treated units, although in principle we could focus on either group. We then conduct the following analysis on this sample.

First, we compute unit-weights for the synthetic control group following the constrained and normalised minimisation problem of differences between the mean observed pre-treatment outcome between treated and controls.

$$\widehat{\omega}^0_{z,h,p}, \widehat{\omega}_{z,h,p} = \text{argmin}_{\omega^0, \omega^{sdid}} \sum_{t=z-p}^{z-1} \left(\omega_0 + \sum_{i=1}^{N^{co}_{z,h,p}} \omega_i Y_{i,t} - \sum_{i=N^{co}_{z,h,p}+1}^{N^{co}_{z,h,p}+N^{tr}_{z,h,p}} \frac{1}{N^{tr}_{z,h,p}} Y_{i,t} \right)^2 + \zeta^2 p ||\omega||_2^2$$

subject to the constraint that the set of ω_i lies on the boundary of the simplex, i.e. $\sum_{i=1}^{N^{co}_{z,h,p}} \omega_i = 1$. ζ is a normalisation constant where we utilize the parametrisation defined in Arkhangelsky et al. (2021) and $||\omega||_2$ is the L2-norm of unit-weights.

Second, we compute weights for the pre-treatment periods that for control units best predict outcomes in the post-treatment period.

$$\widehat{\lambda}^0_{z,h,p}, \widehat{\lambda}_{z,h,p} = \text{argmin}_{\lambda^0, \lambda^{sdid}} \sum_{i=1}^{N^{co}_{z,h,p}} \left(\lambda^0 + \sum_{t=z-p}^{z-1} \lambda_t Y_{i,t} - \frac{1}{h+1} \sum_{t=z}^{z+h} Y_{i,t} \right)^2 + \zeta^2_{time} ||\lambda||_2^2$$

subject to the constraint $\sum_{t=z}^{z+h} \lambda_t^{scdid} = 1$. These correspond exactly to the specification in Arkhangelsky et al. (2021) if the observed cohort were the only cohort analysed. We then estimate cohort-specific average treatment effects on the treated $\tau^h_{z,t,p}$ where $t \leq h$ is the horizon of observation and h is the maximum horizon observed in cohort (z, h, p) as

$$\begin{aligned} \widehat{\tau}^h_{z,t,p} = & \left(\sum_{i=N^{co}_{z,h,p}+1}^{N^{co}_{z,h,p}+N^{tr}_{z,h,p}} \frac{1}{N^{tr}_{z,h,p}} Y_{i,t} - \sum_{i=1}^{N^{tr}_{z,h,p}} \widehat{\omega}_i^{scdid} Y_{i,t} \right) \\ & - \sum_{l=h-p}^{h-1} \lambda_l \left(\sum_{i=N^{co}_{z,h,p}+1}^{N^{co}_{z,h,p}+N^{tr}_{z,h,p}} \frac{1}{N^{tr}_{z,h,p}} Y_{i,l} - \sum_{i=1}^{N^{tr}_{z,h,p}} \widehat{\omega}_i^{scdid} Y_{i,l} \right) \end{aligned}$$

This yields a cohort-horizon-specific effect at each point for the cohorts. For every cohort,

we only retain $\tau^h_{t,h,p}$, i.e. the post-treatment effect at the horizon h for which the cohort (z, h, p) was selected. This ensures that no treated unit is double-counted in any of the horizon-specific post-treatment estimates. We then aggregate horizon-specific ATTs as

$$\widehat{\overline{\tau}}_h = \sum_z \sum_p \frac{N^{tr}_{z,h,p}}{\sum_z \sum_p N^{tr}_{z,h,p}} \widehat{\tau}^h_{z,h,p}$$

For pre-treatment periods, we aggregate horizon-specific effects but retaining all estimates generated. The pre-treatment estimates are not an indication of parallel trends but rather serve as an indication whether the computation of the synthetic control group successfully manages to match pre-treatment outcomes. Any deviations from zero imply that the estimator is not reliable. By contrast, pre-treatment estimates close to zero are not sufficient to infer that the identifying assumptions of the estimator hold.