Automated information sharing and supplying multinationals: Evidence from firm-to-firm data*

— Preliminary and incomplete, please do not circulate —

Márta Bisztray† KRTK, Corvinus University Budapest

Balázs Muraközy University of Liverpool, KRTK

Dzsamila Vonnák KRTK

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Abstract

This paper investigates, by using unique administrative data on firm links and ICT technologies, the extent to which information technologies supporting the integration of suppliers' internal processes and their cooperation with other firms along the supply chain are related to supplying multinationals (MNEs), or, more generally, to integration into global value chains (GVCs). We present a simple model in which suppliers' information technology complements MNEs' technology and suppliers choose their information systems endogeneously. We use detailed data on firms' ICT use linked to administrative firm-to-firm data on supplier-buyer relationships from Hungary to investigate these relationships. We focus on technologies allowing automated information sharing (AIS) either internally or externally. Investigating first at the link level, we find that having external AIS is correlated with supplying an MNE. Second, we show that a similar relationship holds regarding the share of MNEs in new buyers. Finally, firms with more multinational buyers are more likely to introduce external AIS technologies. We also find evidence that these relationships partly result from complementarity between suppliers' and MNEs' AIS technologies. Regarding policy, the complementarities documented suggest that promoting AIS technologies may help SMEs' integration into GVCs and may also generate multiplicator effects with providing incentives for firms further upstream in the supply chain to introduce these technologies.

keywords: ICT, MNEs, GVCs, automated information sharing, network formation, propagation of technologies, linked microdata

JEL-codes: D22, F23, L14, O33

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†Corresponding author: Márta Bisztray: Institute of Economics, KRTK, 1097 Tóth Kálmán u. 4., Budapest, Hungary. Email: bisztray.marta@krtk.hu

1 Introduction

Integration into global value chains (GVC) by supplying multinationals (MNEs) or other globally integrated firms is often considered to be a key aim in domestic firms' strategy. Such integration does not only provide access to productive partners and large markets, but can also generate positive productivity spillovers for suppliers (e.g Javorcik 2004, Blalock & Gertler 2008), partly resulting from technology upgrading. However, becoming a supplier of MNEs requires firms to be productive and to use "sophisticated technology", so MNEs can use the inputs seamlessly in their production process—a complementarity between the two firms' technology. Furthermore, even when a relationship is established, the productivity spillovers may depend on the absorptive capacity or technology level of the supplier, often captured as the supplier's productivity (e.g Havranek & Irsova 2011).

Most papers studying which firms supply MNEs and suppliers' technology upgrading focus on productivity, a very indirect measure of technology.[1] There is much less evidence about the role of specific technologies in these relationships.[2] Such research can not only provide a more direct picture of the mechanisms behind GVC integration and technology spillovers, but can inform policy about the type of technological change that promotes GVC integration. The main obstacle of studying the role of specific technologies is the lack of data. Most datasets used to study spillovers from supplying MNEs lack data on individual transactions, even though recently such data has become available (see e.g. Alfaro-Urena et al. 2019). Information on specific technologies is also scarce. In this paper we combine information on firm-to-firm links with surveys about the specific information technologies used by firms to provide a sharper picture.

We focus on specific information technologies which allow automated information sharing (AIS) within and across firms. Internal AIS helps in integrating information flows across different functional areas within firms. This can be done with an Enterprise Resource Planning (ERP) system (a leading example for which is SAP), and/or by sharing information across functional areas about customers using a Customer Relationship Management (CRM) system (a leading example being Salesforce). External AIS implies precise and easy-to-process information transmission across firms by sharing relevant information with supply chain partners in an automatized way (SC AIS) and/or sending information to buyers or suppliers in such a way that their own information systems can process it automatically (Electronic Data Interchange, EDI).

[1] See a review of previous studies on FDI spillovers in the EU in Bruno & Cipollina (2018) and worldwide in Smeets (2008) and Havranek & Irsova (2011). For looking at the characteristics of MNE suppliers, an example is Javorcik & Spatareanu (2009b).

[2] Some papers look at the more specific impact of FDI on local firms' exporting activity (Greenaway et al. 2004), quality upgrading of exports (Harding & Javorcik 2012) or innovativeness (Crescenzi et al. 2015)

The use of these technologies by suppliers may be strongly complementary to MNEs' technology. Internal AIS systems may guarantee that suppliers' production, quality and timing will become more reliable, which is important for MNEs' technology as it relies on such features of input supply.[3] The external AIS of suppliers provides important information which can be automatically processed by MNEs' own information system, reducing transaction costs.

Importantly, the introduction of these technologies seems to have a non-trivial cost. There is a large gap between smaller and larger firms in terms of both internal and external AIS technology use, and the majority of SMEs did not report using such systems even in European countries with the highest penetration of these technologies (see Figure 1).

Based on these observations we build a simple model to analyse potential complementarities between suppliers' information technology and the MNEs' technology to guide our empirical work. The model allows for heterogeneity both on the supplier and the buyer side, for endogeneous supplier technology choice and link formation. The model suggests that a positive correlation between suppliers' ICT technology and the share of MNEs along its buyers provides evidence for complementarity when conditioning on the number of the supplier's buyers and the share of MNEs among its potential buyers. Suppliers with more (potential) MNE buyers are also more likely to introduce complementary technologies conditional on their productivity.

During our empirical analysis, we build on two panel databases. The VAT database is an administrative dataset of transactions between firms. It includes all transaction links between domestic firms above a small threshold (around EUR 10,000 per year) between 2015 and 2019. These data can be linked to balance sheet data as well as to a survey on enterprise information and communication technology use. This ICT use survey, which is harmonised across EU countries, covers a representative sample of 5,000-7,000 firms per year with at least 10 employees. The ICT survey asks about a number of specific technologies used by the firm, including the above mentioned automated information sharing technologies. Besides that, it also allows us to calculate indices capturing the general ICT use of the firm. Including internal AIS, external AIS and general ICT indices jointly in regressions allows us to separate the effect of the specific technologies from that of other ICTs.

We use three approaches to study these relationships. We start with a link-level approach and ask whether suppliers with AIS technologies are more likely to have links with MNEs. This approach allows us to control both for buyer and supplier heterogeneity with fixed effects as well as for a number of pair-specific variables. We find that, indeed, suppliers with higher external AIS use are more likely

[3]Based on survey results on Czech firms Javorcik & Spatareanu (2005) find that problems with product quality and timely delivery are important factors preventing the formation of supplier links with multinationals.

to supply MNEs, suggesting that supplier AIS complements the general technology used by MNEs. We also provide evidence that this complementarity partly results from the complementarity between the two firms' AIS technologies.

Second, we show that firms using more external AIS technologies "initially" (in 2015) acquire a higher share of new MNE buyers subsequently. We also show that this may be driven by complementarity between supplier's and buyer's external AIS.

Finally, we focus on the introduction of new AIS technologies and find that suppliers with a higher share of MNE buyers initially (in 2015) are more likely to introduce subsequently both external AIS technologies: automated sharing of supply chain information and Electronic Data Interchange. In addition, we find that suppliers which have more buyers with external AIS technologies are more likely to introduce an external AIS technology themselves, which may, again, partly explain the link between MNE buyers and external AIS introduction.

Our results support that automated information sharing technologies, especially those which allow firms to communicate with other firms more effectively, seem to be complementary with the technology which MNEs tend to use. Introducing these technologies may help firms to acquire MNE buyers and, eventually, to integrate more effectively into global value chains. Policymakers aiming at such integration may consider promoting these AIS technologies which are used only by a minority of SMEs even in the most tech-savvy European countries.

Our findings on endogenous technology choice showing that suppliers are more likely to introduce external AIS technologies if they have MNE buyers and/or buyers also using the same technology, suggest the presence of network effects in these technologies. MNE entry or the introduction of such technologies by a subset of firms can trigger the introduction of technologies by other firms in the supplier-buyer network. This finding suggests a specific mechanism behind vertical spillover effects from MNEs. Further, such network effects hint at the presence of multiple equilibria, which may provide important rationale for MNE or ICT promotion policies.

Our paper contributes to different strands of the literature. First, we contribute to the literature on the role of firm characteristics in entry into global value chains. A large literature has shown that entry into foreign markets via exporting is associated with a productivity premium (summarized by Bernard & Jensen 2004, Wagner 2007, De Loecker 2007, Wagner 2012). A number of papers have also documented that suppliers of multinationals also tend to have a higher productivity level (e.g. Javorcik 2004, Havranek & Irsova 2011, Bruno & Cipollina 2018). While productivity is an aggregate measure of firm technology, it is not easy to infer the types of exact factors that play a role in being able to

serve multinationals and other productive firms. A relatively small literature has investigated the role of more specific factors. For example, Javorcik & Spatareanu (2009a) shows the role of liquidity in these decisions. We contribute to this literature with using a comprehensive data to identify the role of specific information technologies in becoming multinational suppliers.[4]

Second, the literature on vertical spillovers from FDI has established that becoming a supplier of an FDI (e.g. Javorcik 2004, Godart & Görg 2013), having links to a more productive firm via employee mobility (e.g. Stoyanov & Zubanov 2012) or integrating into GVCs in general (e.g. Del Prete et al. 2017) has a positive effect on productivity. Our paper contributes to this literature by documenting a specific channel of spillover effects or technology upgrading: firms supplying multinational clients being more likely to introduce automated information sharing technologies, which in turn, may help them in acquiring more MNE or high-productivity clients.

Third, our research is also linked to the literature on connections between ICT and productivity. There are numerous papers establishing a positive effect of ICT on productivity (see e.g. Bloom et al. 2012, or Draca et al. 2006, Cardona et al. 2013 and Kretschmer 2012 for a survey). There are fewer papers looking at specific technologies (e.g. Akerman et al. 2015, investigate the role of broadband adoption). Here our aim is not to investigate the effect on productivity in general. Instead, we focus on a distinct channel, supplying MNEs, through which specific ICT usage can increase firm productivity.[5]

In what follows, Section 2 discusses our simple theoretical framework, Section 3 presents the data we use and Section 4 describes our empirical strategy. Section 5 provides the main results while Section 6 concludes.

2 Background

2.1 The sources of complementarity

The higher productivity of multinationals may have a number of sources. Syverson (2011) discusses five main sources of plant-level productivity differences in general: i) Management, ii) Higher quality capital and/or labour, iii) IT and R&D, iv) Learning by doing and v) Product innovation. Assuming multinationals' productivity advantage results from one or more of these sources, we can discuss how

[4]The role of broadband internet, a general technology behind ICT applications has been studied in the exporting context by Hagsten & Kotnik (2017) and Kneller & Timmis (2016).

[5]There is some evidence from previous literature for ICT playing a role in attracting FDI to a specific location (Gholami et al. 2006).

these factors may interact with suppliers' AIS technologies.

First, better management systems, according to Bloom & Van Reenen (2007), involve effective monitoring, target setting and providing well-designed incentives. All these hallmarks of efficient management require easy access and processing of information, which may be made easier by relevant and well-structured information arriving from suppliers. Second, higher quality capital, including human capital, may be complementary to information and data, including information from suppliers. Third, if MNEs operate effective ICT systems—including AIS systems themselves—, those systems may clearly benefit from well-designed inputs from suppliers. Finally, more innovative products produced by MNEs may also benefit from high and consistent quality of inputs as well as relevant information about inputs (Javorcik & Spatareanu 2005). The former may be both enhanced and signaled by effective internal supplier AIS systems, while the latter may be supplied by supplier AIS. All these arguments suggest that these four sources of MNE technological advantage are likely to be complementary to suppliers' AIS systems.

The potential complementarity between the two firms' AIS systems is testable with our data, in which we have information both about supplier and buyer ICT. Our results indicate that this specific technological complementarity may, indeed, be one of the sources of the complementarity between suppliers' ICT and MNEs' technology in general.

2.2 Model

In this section we present a simple model to motivate our empirical specifications. Our framework captures the following features: i) the complementarity between suppliers' ICT technology and the technology used by buyers, ii) buyer and supplier heterogeneity and, iii) endogenous ICT choice by the supplier and endogeneous link formation. In line with the nature of our data, we use a framework where both suppliers and buyers can have multiple partners. Note that it is relevant, because ICT introduction is a firm-level decision, and, therefore it depends on the number of buyers.

In our theoretical framework, firms are either suppliers or buyers. Suppliers can introduce an ICT technology in period 0. Link formation takes place in period 1. Suppliers (indexed by i) are heterogeneous in terms of their "appeal" (η_i) and in terms of their pool of potential buyers, which is characterised by the share of MNEs in the buyer pool (μ_i), even though the mass of potential buyers is the same for all suppliers, normalised to 1. The differences in buyer pool may arise as a result of geographic or industry differences. Buyers, denoted by j, in turn, can be either multinational

($MNE_j = 1$) or not ($MNE_j = 0$) and have a demand or "quality" of ξ_j. We allow the ξ_j distribution to differ for MNE and other firms, denoted by $f^{MNE=1}(\xi)$ and $f^{MNE=0}(\xi)$, respectively. Suppliers with buyer pool μ_i draw μ_i potential buyers from the $f^{MNE=1}(\xi)$ distribution and $1-\mu_i$ from $f^{MNE=0}(\xi)$.

In particular, we assume that $\xi \geq 1$ and these distributions are Pareto, with parameters α^M and α^D for MNEs and other potential buyers, respectively:

$$\begin{aligned} \mathcal{F}^{MNE=1}(\xi) &= 1-\xi^{-\alpha^M} \\ \mathcal{F}^{MNE=0}(\xi) &= 1-\xi^{-\alpha^D}. \end{aligned} \tag{1}$$

Motivated by evidence that MNEs in general perform better than non-MNE firms (Blonigen et al. 2014), we assume that the expected value of the MNE ξ distribution is larger, implying $1 < \alpha^M \leq \alpha^D$.

In period 0, suppliers decide on whether to introduce the ICT technology. Introducing the technology will generate a larger surplus from each relationship in period 1, but the introduction has a fixed cost $FI > 0$. The outcome of this decision is denoted by ict_i, a binary variable, which shows whether firm i has introduced the information technology. Suppliers receive a θ share from the surplus.

Link formation takes place in period 1. This requires a fixed cost of $FL > 1$ per link, and all links which generate a larger surplus than this fixed cost are established thanks to efficient bargaining. The surplus generated is modeled with an O-ring (Kremer 1993, Aghion et al. 2017) technology. The surplus of a link between supplier i and buyer j is:

$$F(ict_i, MNE_j, \eta_i, \xi_j, \lambda) = \lambda \times ict_i \times MNE_j + (1-\lambda)\,(ict_i + MNE_j) + \eta_i + \xi_j + \epsilon_{ij} \tag{2}$$

where MNE_j, an indicator, represents the MNE status of potential buyer j, capturing firm size, productivity and the information technologies used by that firm. $0 \leq \lambda \leq 1$ shows whether there is complementarity between the suppliers' ICT technology and the technology used by multinationals. ϵ_{ij} is a pair-level idiosyncratic term representing match quality.

We also restrict the range of η_i so that each supplier will have a threshold buyer with a ξ_j level within the range of $\mathcal{F}(\xi)$, i.e. $\overline{\xi} \geq 1$. We, therefore restrict the range of η_i as $0 \leq \eta_i \leq FL - 3 + \lambda$.[6]

Let us analyse the decisions backward and start with suppliers' decisions given their information

[6] Based on Equation (3).

technology choice.

Proposition 1. ***Link formation***

1. *If $\lambda < 1$, suppliers with a higher appeal, η_i, or μ_i will have more buyers conditional on ict_i. Suppliers with higher μ_i will also have a higher share of MNE buyers conditional on ict_i.*

2. *If $\lambda \geq 1 - \frac{\alpha^M}{\alpha^D}$, introducing the ict technology leads to an increase in the share of MNE buyers (positive assortativity is in cross section)*

3. *The difference between the increase in MNE buyers and non-MNE buyers after the introduction of ICT relative to their number before the introduction is increasing in the strength of complementarity, λ.*

Proof. A relationship will form if $F(ict_i, MNE_j, \eta_i, \xi_j, \lambda) \geq FL$. For each supplier i, it leads to a threshold $\overline{\xi}_i^{MNE}$ both for MNE and non-MNE firms:

$$\begin{aligned} \overline{\xi}_i^{MNE=1}(ict) &= FL - [\lambda \times ict_i + (1-\lambda)(ict_i + 1) + \eta_i] \\ \overline{\xi}_i^{MNE=0}(ict) &= FL - [(1-\lambda)(ict_i) + \eta_i] \end{aligned} \tag{3}$$

First, both thresholds are clearly decreasing in η_i, implying a positive association between η_i and the number of buyers, $n_i(ict)$.

Second, μ_i does not affect these thresholds, but the supplier with higher μ will sample more from the MNE distribution which has a larger expected value. The mass of buyers is just the weighted average of the share of MNE and non-MNE buyers purchasing from firm i:

$$n_i(ict) = \mu_i \left(\overline{\xi}_i^{MNE=1}(ict)\right)^{-\alpha^M} + (1-\mu_i)\left(\overline{\xi}_i^{MNE=0}(ict)\right)^{-\alpha^D}.$$

As $1 < \alpha^M \leq \alpha^D$, this number is increasing in μ_i.[7]

Third, the ratio of MNE buyers to other buyers is:

[7] Let's denote $FL - [(1-\lambda)(ict_i) + \eta_i]$ with K. Then $\overline{\xi}_i^{MNE=0}(ict) = K$ and $\overline{\xi}_i^{MNE=1}(ict) = K - (1-\lambda) - \lambda \times ict_i$. We have $\frac{dn_i(ict)}{d\mu_i} > 0$ if $\left(\overline{\xi}_i^{MNE=1}(ict)\right)^{-\alpha^M} > \left(\overline{\xi}_i^{MNE=0}(ict)\right)^{-\alpha^D}$. Rearranging gives $K - K^{\frac{\alpha^D}{\alpha^M}} < 1 - \lambda + \lambda \times ict_i$. As $\alpha^M \leq \alpha^D$, the left-hand side is ≤ 0. As $0 \leq \lambda < 1$, the right-hand side is positive and the inequality holds.

$$\text{MNE ratio}_i(ict) = \frac{\mu_i}{1-\mu_i} \frac{\left(\bar{\xi}_i^{MNE=1}(ict)\right)^{-\alpha^M}}{\left(\bar{\xi}_i^{MNE=0}(ict)\right)^{-\alpha^D}} \tag{4}$$

This ratio is increasing in μ, because difference in μ do not affect the thresholds.

Turning to the second statement, we can calculate the percentage increase in MNE buyers as the log number of MNE buyers after the introduction of ICT relative to their number before the introduction:

$$\begin{aligned} \ln\left(\frac{\bar{\xi}_i^{MNE=1}(ict=1)}{\bar{\xi}_i^{MNE=1}(ict=0)}\right)^{-\alpha^M} &= -\alpha^M \ln\left(1 - \tfrac{1}{FL-(1-\lambda)-\eta_i}\right) \\ &\approx \alpha^M \tfrac{1}{FL-(1-\lambda)-\eta_i} \end{aligned} \tag{5}$$

where we used the first-order Taylor approximation, $\ln 1 + x \approx x$ for small values of x. Similarly for non-MNE firms:

$$\begin{aligned} \ln\left(\frac{\bar{\xi}_i^{MNE=0}(ict=1)}{\bar{\xi}_i^{MNE=0}(ict=0)}\right)^{-\alpha^D} &= -\alpha^D \ln\left(1 - \tfrac{1-\lambda}{FL-\eta_i}\right) \\ &\approx \alpha^D(1-\lambda) \tfrac{1}{FL-\eta_i} \end{aligned} \tag{6}$$

We can express the change in the ratio of MNE and other buyers as the difference in these log changes:

$$\begin{aligned} \ln\left(\frac{\bar{\xi}_i^{MNE=1}(ict=1)}{\bar{\xi}_i^{MNE=1}(ict=0)}\right)^{-\alpha^M} &- \ln\left(\frac{\bar{\xi}_i^{MNE=0}(ict=1)}{\bar{\xi}_i^{MNE=0}(ict=0)}\right)^{-\alpha^D} \\ &\approx \alpha^M \tfrac{1}{FL-(1-\lambda)-\eta_i} - \alpha^D(1-\lambda)\tfrac{1}{FL-\eta_i} \end{aligned} \tag{7}$$

This difference is positive under our assumptions because $\lambda \geq 1 - \frac{\alpha^M}{\alpha^D}$, implies that $\alpha^M \geq \alpha^D(1-\lambda)$ and $\frac{1}{FL-(1-\lambda)-\eta_i} > \frac{1}{FL-\eta_i}$. This implies that the introduction of the ict technology leads to an increased share of MNE buyers.

Turning to the third statement, we can also express the difference between the percentage increase in MNE buyers and non-MNE buyers after the introduction of ICT relative to their number before the introduction as follows:

$$\ln\left(\frac{\bar{\xi}_i^{MNE=1}(ict=1)}{\bar{\xi}_i^{MNE=1}(ict=0)}\right)^{-\alpha^M} - \ln\left(\frac{\bar{\xi}_i^{MNE=0}(ict=1)}{\bar{\xi}_i^{MNE=0}(ict=0)}\right)^{-\alpha^D} =$$

$$= -\alpha^M \ln\left(\frac{FL-1-(1-\lambda)-\eta_i}{FL-(1-\lambda)-\eta_i}\right) + \alpha^D \ln\left(\frac{FL-(1-\lambda)-\eta_i}{FL-\eta_i}\right)$$

$$= (\alpha^M + \alpha^D)\ln(FL-(1-\lambda)-\eta_i) - \alpha^M \ln(FL-1-(1-\lambda)-\eta_i) - \alpha^D \ln(FL-\eta_i) \tag{8}$$

The derivative of the above expression with respect to λ is as follows:

$$\frac{\alpha^M + \alpha^D}{FL-(1-\lambda)-\eta_i} - \frac{\alpha^M}{FL-1-(1-\lambda)-\eta_i} = \frac{-\alpha^M + \alpha^D(FL-1-(1-\lambda)-\eta_i)}{(FL-(1-\lambda)-\eta_i)(FL-1-(1-\lambda)-\eta_i)} \tag{9}$$

Since we restricted the range of η_i such that $0 \leq \eta_i \leq FL-3+\lambda$, we have $(FL-(1-\lambda)-\eta_i) \geq 2$ and $FL-1-(1-\lambda)-\eta_i) \geq 1$. Thus the denominator is always positive. Given that $1 < \alpha^M \leq \alpha^D$, the numerator is also positive. So the above expression is positive, implying that the difference between the percentage increase in MNE buyers and non-MNE buyers after the introduction of ICT relative to their number before the introduction is increasing in λ.

□

This theorem shows that firms with ICT technologies are more likely to have a higher share of MNE buyers. A stronger relationship between ICT technologies and the share of MNE buyers is evidence for stronger complementarity.

The second statement in the proposition also implies that complementarity also implies a positive cross sectional relationship between ICT technologies and the share of MNE buyers if one compares similar suppliers in terms of their appeal, μ_i.

Let us now consider period 0, when the firm has the option of introducing the ICT technology for a cost of FI.

Proposition 2. ***Technology choice***

1. *The probability of introducing the technology increases both in μ_i and η_i.*

Proof. The incentive of the firm to introduce the technology depends on the increase in total surplus

from its relationships:

$$\sum_{B_i(ict_i=1)} \theta F(MNE_j, \eta_i, \xi_j, \lambda | ict_i = 1) - \sum_{B_i(ict_i=0)} \theta F(MNE_j, \eta_i, \xi_j, \lambda | ict_i = 0) \geq FI$$

Where B_i is the buyer set of firm i. Introducing the technology has two effects on the firm's surplus. First, on an *intensive margin*, introducing the technology raises the surplus from relationships with customers whom i would supply even if $ict_i = 0$.[8] From Equation (2) the surplus from relationships with MNEs increases with 1 and with non MNEs with $1 - \lambda$ after introducing the ICT technology. We can express the increase in surplus on "intensive margin" buyers as:

$$\text{Intensive effect} = \theta \times \left[\mu_i \times 1 \times \left(\overline{\xi}_i^{MNE=1}(ict) \right)^{-\alpha^M} + (1 - \mu_i) \times (1 - \lambda) \times \left(\overline{\xi}_i^{MNE=0}(ict) \right)^{-\alpha^D} \right]. \tag{10}$$

This effect is increasing in μ_i, because a higher μ_i is associated with supplying more MNEs, and the surplus from MNE clients increases more when the firm introduces the ICT technology. More formally, differentiating this equation with respect to μ_i we get:

$$\begin{aligned} \frac{\partial \text{Intensive effect}}{\partial \mu_i} &= \theta \times \left[\left(\overline{\xi}_i^{MNE=1}(ict) \right)^{-\alpha^M} - (1 - \lambda) \left(\overline{\xi}_i^{MNE=0}(ict) \right)^{-\alpha^D} \right] \\ &= \theta \times \left[\lambda \left(\overline{\xi}_i^{MNE=1}(ict) \right)^{-\alpha^M} + (1 - \lambda) \left(\left(\overline{\xi}_i^{MNE=1}(ict) \right)^{-\alpha^M} - \left(\overline{\xi}_i^{MNE=0}(ict) \right)^{-\alpha^D} \right) \right] \\ &> 0 \end{aligned}$$

In the last but one inequality, $\left(\overline{\xi}_i^{MNE=1}(ict) \right)^{-\alpha^M}$ is just the number of MNEs supplied by the firm, a positive number. In the second term, $\left(\overline{\xi}_i^{MNE=1}(ict) \right)^{-\alpha^M} - \left(\overline{\xi}_i^{MNE=0}(ict) \right)^{-\alpha^D}$ is the difference between the mass of MNEs and other firms above the threshold. Given that the MNE threshold is lower and $1 < \alpha^M \leq \alpha^D$, this difference is also positive.

A higher η_i also leads to a stronger incentive effect, because it reduces the threshold of both MNE and other buyers, increasing the number of both types of relationships which can generate a

[8] Note that introducing $ict = 1$ shifts both $\overline{\xi}_i^{MNE=0}$ and $\overline{\xi}_i^{MNE=1}$ downwards, therefore the $B_i(ict_i = 0) \subseteq B_i(ict_i = 1)$.

surplus. More formally, differentiating Equation (10) with respect to η_i and using the definitions of the thresholds in Equation (3), we get:

$$\begin{aligned}\frac{\partial \text{Intensive effect}}{\partial \eta_i} &= \theta \times \left[\alpha^M \mu_i \left(\bar{\xi}_i^{MNE=1}(ict)\right)^{-\alpha^M-1} + \alpha^D(1-\mu_i)(1-\lambda)\left(\bar{\xi}_i^{MNE=0}(ict)\right)^{-\alpha^D-1}\right] \\ &> 0\end{aligned}$$

Second, on the extensive margin, the introduction of the new technology reduces the threshold according to Equations (5) and (6) , generating further surplus.

□

This framework clarifies a number of issues for our empirical exercise. Importantly, positive assortativity, conditional on the number of buyers and buyer pool, is indeed in line with complementarity between the two firms' technologies. Stronger assortativity is evidence for stronger complementarity. Also, having more MNEs in the pool of potential or actual buyers (larger μ_i) provides incentives to introduce the technology, leading to propagation.

Regarding estimating complementarity, the framework provides two important insights. First, the relevant assortativity is conditional on supplier appeal (η_i) and the type of potential buyers (μ_i). Introducing the ICT technology allows suppliers to trade with more buyers, and this can lead to a large number of non-MNE buyers, depending on the ξ distribution. But as Proposition 1 part ii) shows, the share of MNE buyers will be higher for ICT-using firms conditional on these characteristics, η_i and μ_i. Empirically, we will handle this issue either by controlling for different measures for firm size/number of buyers and a rich set of fixed effects or by running dyadic regressions in which we can control for supplier fixed effects to capture differences in the number of firms served.

Second, a positive assortativity between supplier and buyer technology may be confounded by enodogenous technology choice of suppliers. Indeed, the quality of the potential buyer set (μ) affects positively both ICT introduction and the average MNE share of the actual buyers of supplier i. We can use a number of different approaches to alleviate this issue. First, if the set of potential buyers is industry and/or region specific, industry/region fixed effects can provide a solution. Second, by following on a diff-in-diff style strategy we may estimate how the level of ICT affects the type of new buyers, conditioning out time-invariant firm unobservables.

Turning to technology propagation, note that this works via the channel that firms have higher incentives to introduce technologies if they have more potential MNE buyers.[9] Therefore, the relationship of interest is between technology choice and μ. One measurement issue is that this relationship may be confounded by η, appeal, because higher appeal leads to a higher number of buyers, given the set of buyers, strengthening incentives to introduce the technology. Therefore, we need to control for appeal in our regressions, with including again the number of buyers or firm size measured with sales.

3 Data

We build a novel dataset by combining detailed data on ICT usage and supplier networks. The data contains the exact links between firms and specific ICT technologies. In this section we discuss in detail the data sources that we use to compile our database.

3.1 Data sources

Corporate financial statement panel First, we use the corporate financial statement database collected by the National Tax and Customs Administration. The database is available annually between 2000 and 2018. It contains balance sheet and profit&loss statements data of all double-entry bookkeeping Hungarian enterprises. Besides the financial data it also contains some basic information of the firms, such as the industry code of the firm, the number of its employees, its date of establishment, the location of its headquarters and whether it is domestically- or foreign-owned.

Survey on ICT use Second, we use a survey data on ICT use. The survey is called "Survey on quantitative and qualitative data of the information and communications technology stock" and is harmonized at the EU level. In Hungary the data collection is conducted by the Central Statistical Office (CSO). The data covers a representative sample of firms with at least 10 employees. The data is available annually between 2007 and 2018. It contains around 5,000-6,500 firms in each year.[10]

VAT database Third, we use the value added tax (VAT) database collected by the National Tax and Customs Administration. This is a firm-to-firm administrative data containing all transactions

[9] Our model abstracts from learning and other similar effects. Note that the technologies we study are quite well known, so learning may play a smaller role. However, our estimates capture the effect of learning as well as the incentive effects.

[10] Further information about this survey and the questionnaires are available at https://ec.europa.eu/eurostat/cache/metadata/en/isoc_e_esms.htm.

above a small value threshold. The data is available between 2015 and 2019. The data contains those taxable firms liable for the payment of VAT, which have a transaction above some value threshold. These firms report data on transactions separately for each of their business partners with which they had transactions above a low threshold (around EUR 10,000). Firms report transactions both with their suppliers and buyers. The main variable is the value of transactions with the partner each year.

Linking the data We can merge these three databases by using the same anonymized identifier. Nearly all firms in the VAT and the ICT use data can be merged to the financial statement data. 90-96% of the firms in the ICT data can be matched with the financial statement panel that year. While only about two third of the VAT data transactions can be linked to both buyer and supplier firms being present in the balance sheet data with non-missing employment and sales data, a large fraction of these non-matched transactions comes from registered purchases from large partners which don't have a Hungarian tax identifier, like Amazon. Focusing on the subset of manufacturing firms, which we will include in the empirical analysis, only about one third of them has a matched ICT use data in a particular year.

3.2 Variables

One of our key variables is whether a firm is an MNE, a foreign-owned firm which is integrated into global value chains. While foreign ownership is available in the financial statement data, not all foreign-owned firms can be considered being parts of global value chains or using the sophisticated technologies we are interested in here. Therefore, we choose a conservative approach and define MNEs as the largest foreign-owned firms, i.e. firms with at least 500 employees and 10% foreign share.[11]

Our second set of key variables are the ones representing each firm's ICT usage. From the ICT use survey, we create two key measures of automated information sharing: internal (i.e. integration of processes within the firm) and external (i.e. the extent and the way of information sharing with partners). Additionally, we compose a general ICT use index to capture other aspects of ICT usage within the firm.

The *Internal AIS index* contains two variables. First, *ERP* or Enterprise Resource Planning is defined as "a software package used to manage resources by sharing information among different

[11] According to the Hungarian Central Statistics Office, the average size of foreign-controlled but not necessarily MNE firms was 180 employees in 2018, and in 2003 MNE affiliates operated in Hungary in 2009. (https://www.ksh.hu/stadat_files/gsz/en/gsz0019.html and https://www.ksh.hu/stadat_files/gsz/en/gsz0023.html). Our manufacturing sample contains only 160 MNE buyers with an average size of 1297 employees.

functional areas (e.g. accounting, planning, production, marketing, etc.)". A key example for this is SAP. Second, *CRM* or Customer Relationship Management is defined as "any software application for managing information about customers". A key example for this software if Salesforce.[12]

We use another two variables to define the *External AIS index*. The first is "Enterprises whose business processes are automatically linked to those of their suppliers and/or customers" (*SC AIS*), which is based on the question "Did your enterprise share information electronically on supply chain management with its suppliers or customers?". This is defined as "exchanging all types of information with suppliers and/or customers about the availability, production, development and distribution of goods or services. This information may be exchanged via websites, networks or other means of electronic data transfer, but it excludes manually typed e-mail message". The second variable linked to external information sharing is *EDI* or Electronic Data Interchange type sales, defined as the "enterprise receive orders for goods or services placed via EDI-type messages". EDI-type messages are "an agreed or standard format suitable for automated processing (e.g. EDI (e.g. EDIFACT), XML (e.g. UBL)), without the individual messages being typed manually".

To control for cross-firm differences in ICT use beyond information sharing, we create an additional *General ICT index* from three variables: share of employees using computers for business purposes, use of a website and use of cloud computing services.[13]

We calculate each of the indices as the simple average of the components. As all the components are binary variables or shares, the values of the indices are also between zero and one. Missing values may occur due to two main reasons. First, the questionnaire changes to some extent across the years, thus not all the variables are available in each year.[14] Second, as it is a survey, not all the firms are included every year.[15] To fill in the gaps, we impute the first lags or leads if a variable is missing in a year.[16]

Figures 2 and 3 present baseline patterns of our main measures. Figure 2 shows yearly averages

[12] All the ICT variable definitions are from the 2015 Survey.

[13] Cloud computing services are defined as "ICT services that are used over the internet to access software, computing power, storage capacity etc., where the services have all of the following characteristics: are delivered from servers of service producers; can be easily scaled up or down (e.g. number of users or change of storage capacity); can be used on-demand by the user, at least after the initial set up (without human interaction with the service provider); are paid for, either per user, by capacity used, or they are pre-paid. Could computing may include connections via Virtual Private Networks (VPN)." (From the 2015 questionnaire.)

[14] Data on ERP and CRM is not available in 2011, 2016 and 2018. Question on SC AIS was not included in 2007, 2011, 2013, 2016 and 2018. Data on EDI-type sales is only available from 2011 on and a question on cloud computing is only included from 2014 on.

[15] 36% of all the firms ever included in the survey in the period 2007-2018 were included in only one wave, but 26% was included in at least 5 waves.

[16] For those cases in which only one (or two but not all) component(s) of the index is still missing, we impute the yearly average of the variable to calculate the index.

of ICT variables and indices. There are considerable differences across the variables in terms of prevalence. While almost 80% of the companies has a webpage, all the other technologies are present in less than 40% of the firms. There are differences even within the technologies connected to automated information sharing, external AIS being less widespread than internal AIS. These patterns persist over time within our period of interest. Figure 3 presents adoption patterns, showing the share of firms introducing a specific technology between 2015 and 2017, compared to the share of users in 2015. Increase in technology usage is 14-26% of initial prevalence, affecting a non-negligible number of firms. We present further descriptive patterns of our data in the Data Appendix.

4 Empirical approach

We use three approaches to investigate the relationship between suppliers' ICT technologies and supplying MNEs. We start with a link-level, cross sectional approach followed by investigating whether suppliers using AIS technologies acquire more MNE clients, and finally, we study whether suppliers selling to more MNEs are more likely to introduce AIS technologies. In each case, we also ask whether suppliers' AIS technology appears to be complementary to buyers' AIS technologies.

4.1 Link-level approach

We run regressions at the level of potential supplier-buyer pairs and investigate whether firms with AIS technologies are more likely to supply MNEs. This approach has been used to study a number of network-related questions (e.g. De Paula 2020, Dzemski 2019).

In particular, we run conditional logistic models to predict which of the potential links exists in a cross section:

$$logit(W_{icj}) = \beta_1 ict_i + \beta_2 MNE_j + \beta_3 ict_i \times MNE_j + \gamma X_{ij} + \alpha_c + \epsilon_{icj} \tag{11}$$

where W_{icj} is a binary variable showing whether firm firm j chooses firm i as a supplier in choice c, with choice c being defined as firm j having a supplier from the industry of firm i.[17] ict_i is the ICT use of firm i and the MNE_j is the MNE status of firm j. The variable of interest is the interaction $ict_i \times MNE_j$. X_{ij} is a vector of variables showing supplier and buyer characteristics as well as bilateral

[17] Based on XXX one choice is composed of the chosen firm and a random sample of 20 from the not chosen firms operating in the same industry. If two firms from the same industry supply firm j, we consider these as two separate choicec.

attributes. ict_i in our specifications is a vector, which includes the internal AIS, external AIS and general ICT indices — as well as an indicator for having no information about firm i's ICT — to allow us to distinguish between these different information technologies. The choice fixed effect, α_c captures the attractiveness of buyer j. We control for firm size and productivity, also interacted with MNE_j, to control for the appeal of i and the number of firms it tends to supply. ϵ_{ij} is the error term clustered by j.

Our parameter of interest is β, which measures the correlation between supplier ICT and MNE technology. If this variable is positive, suppliers with AIS are more likely to serve MNEs, conditional on the other variables. According to Proposition 1, we need to control for the number of partners (or firm size) as well as the share of multinationals in the possible buyer pool of supplier i. We control for the number of partners by including supplier characteristics such as size and productivity. Choice fixed effect capture industry differences in the composition of potential buyers. We also control for log distance, to capture trade costs between the two firms.

Another key problem when interpreting the β as an indicator for complementarity between supplier ICT and MNE technology is that it may reflect other types of complementarity, including complementarities resulting from economies of scale when two large firms can more effectively transact with each other. This biases the estimated β if ICT use is correlated with size and productivity. Therefore, we control for the interactions of firm size and productivity.

In separate regressions we also test for specific complementarity between the two firms' ICT technologies. In these specifications we replace $ict_i \times MNE_j$ with $ict_i \times ict_j$ in Equation (11). The coefficient of this variable shows whether suppliers with AIS technologies are more likely to serve buyers with the same technology.

4.2 Type of new partners

In our second approach, we are interested in how suppliers' initial ICT technology in t_0 is related to the sales-weighted share of MNEs among firm i's new buyers. New buyers are defined as firms with whom the firm started a new relationship in the 2-year period following t_0. In particular, we run the following regression

$$\text{MNE share new}_{it} = \beta \times ICT_{i,t_0} + \gamma \times X_{i,t_0} + \epsilon_{it} \tag{12}$$

where ICT_{i,t_0} represents the ICT indices of supplier i in t_0, X_{i,t_0} represents controls, which include log employment, log productivity level and industry dummies, while MNE share new$_{it}$ is the sales-weighted share of MNEs among the new buyers of firm i, acquired between t_0 and $t_0 + 2$.[18]

Our parameter of interest is β, showing whether suppliers with specific ICT technologies tend to acquire a higher share of MNE buyers. We attempt to control for firm size and for the share of MNEs among potential buyers (Proposition 1). Regarding firm size, we condition on supplier size both by including it as a control variable and by using a share as the dependent variable. Another problem is that firms may introduce the ICT technology as a response for having more (potential) MNE buyers (higher μ). We alleviate this problem with concentrating only on new buyers and lagging the ICT variable. In other words, we compare ICT and non-ICT firms with similar characteristics in t_0, and ask whether the firm with the *ict* technology acquires more MNE buyers afterwards. In some specifications we also control for the share of MNE buyers in t_0, as a proxy for μ_i. Other controls, productivity and industry dummies, aim to capture variables which can be related to the quality of potential buyers.

Additionally, to investigate the possibility that the AIS technologies of buyers and suppliers complement each other, we re-run our regressions with the share of new buyers having the specific technologies as the dependent variable.

4.3 Introduction of ICT technology

Our third approach is to investigate the introduction of AIS technologies. We study this question with regressions in which the dependent variable shows whether the firm introduces a specific ICT technology after t_0 and the explanatory variable of interest is the share of MNEs among the firm's partners in t_0. We only include firms which did not have the ICT technology in t_0.

In particular, we estimate the following regression:

$$\text{Introduces ICT}_i = \beta \times \text{share of MNE buyers}_{i,t_0} + \gamma X_{i,t_0} + \epsilon_i \tag{13}$$

where Introduces ICT$_i$ shows whether the firm introduced an ICT technology after t_0. The variable of interest is share of MNE buyers$_{i,t_0}$, capturing the initial share of MNE buyers. In our empirical implementation, $t_0 = 2015$ and we investigate whether firms introduce an ICT in 2016 or 2017.

[18] We only consider new buyers which purchase at least 1% of the supplier's output and purchase from the supplier in at least 2 consecutive years.

The key empirical difficulty when estimating this equation is that — as we have discussed it related to Proposition 2 — the firm's incentive to introduce the technology depends both on the number of its buyers and their technology use. To estimate propagation, we would like to focus on the channel from technology use (measure the effect of μ_i rather than η_i). Therefore, we control for firm size (with the number of employees) and productivity which may be related to ICT use via other channels, for example if higher productivity in itself requires more ICT. Note that with including both employment and productivity, we also capture value added, a proxy for the quantity of transactions.

5 Results

5.1 Link-level

Table 1 reports the regressions from Equation (11) investigating whether firms with internal and external AIS systems are more likely to have links with MNEs by interacting variables characterising the supplier's information technology with whether the buyer is an MNE. Column (1) investigates the role of internal AIS and finds that suppliers with that technology are not significantly more likely to form a link with MNEs. Column (2) investigates the relationship between the supplier's external AIS and whether the buyer is an MNE, finding a significant effect, both statistically and economically.[19] These results are in line with complementarity between supplier's external AIS technologies and the technology used by MNEs.

These regressions include a very rich set of controls. Choice fixed effects absorb any heterogeneity of the input-output structure of different industries, as well as the demand of the buyer. Supplier productivity and size account for the appeal of the supplier firm, as suggested by Proposition 1. These capture the key dimensions of firm heterogeneity, such as η_i, ξ_j, μ_i. Further, we control for the distance between the two firms, which has the expected negative coefficient.

The remaining controls are motivated by concerns that supplier AIS technologies may be correlated with other supplier features which can be complementary to the technology used by MNEs. First, AIS systems are likely to be highly correlated with the firm's general ICT use, which may, in itself, be complementary to MNE technologies. Therefore, we control for the interaction of a proxy for the supplier's general ICT use and the buyer's MNE status. This variable has a strong and positive

[19] In Tables A7 and A8 of the Appendix we run similar regressions using a linear probability model in which we include buyer fixed-effects, supplier fixed-effects and buyer industry-supplier industry fixed effects. In these specifications interactions with both types of AIS have significantly positive coefficients. Coefficient estimates are about 70% of the baseline probability.

coefficient, confirming the assortativity, but the AIS variables remain significant suggesting that those specific technologies are also complementary with the technology used by MNE's. Second, AIS and ICT usage is likely to be correlated with the supplier's productivity, which may, again, be complementary to the buyer's technology. We interact supplier productivity both with buyer MNE status and productivity to control for this potential confounder fully, and find positive coefficients, but again, AIS technologies remain significant.

Our second question is whether the suppliers' AIS technologies are complementary to buyers' similar technologies. Table 2 shows the regressions. The setup is very similar to Table 1, but here our variables of interest are the interactions between supplier and buyer AIS technologies. Column (1) includes the interaction between the two firms' internal AIS technologies. The estimated coefficient, 0.2 is statistically only weakly significant. In column (2), we look at the interaction between the two firms' external AIS technologies. We find that the complementarity coefficient is significant, even controlling for the interaction between the two firms' general ICT index.

To sum up, these specifications show significant positive assortativity between the seller's external AIS technology and the share of MNE buyers as well as the share of buyers using a similar technology. These findings suggest substantial complementarity between the two firms' technology. Importantly this is only true for automated information sharing between but not within firms, suggesting that mainly the external AIS technologies are relevant for link formation.

Table **??** checks the main driver behind the relationship we find between external AIS technologies and supplying MNEs. It includes multiple buyer characteristics at the same time, interacted with the supplier's AIS index, also controlling for the general ICT measure and the productivity of the supplier, interacted with the buyer's MNE status. When we look at internal AIS in column (1), it seems to matter for supplying productive buyers in general, but not foreign, large or MNE buyers in particular. Results are not robust for including additional buyer characteristics as the exporter status and the internal AIS index of the buyer in column (2). In column (3)-(4) we present similar estimates for the external AIS index of the supplier. We find that even controlling for the size, foreign-owned status, productivity, exporter status and external AIS index of the buyer, firms with external AIS still have a significantly higher probability of supplying MNEs. Even though complementarity between external AIS technologies seems to be an important channel, as column (4) suggests, this is not the only driver. There are other features of the MNE technology being complementary to the external AIS of the supplier beyond the external AIS of the buyer.

Tables A9 and A10 of the Appendix show that the above patterns are not driven by foreign

suppliers. External AIS technologies play no significantly different role for foreign firms to become MNE suppliers or suppliers of firms with external AIS technologies. Table A11 of the Appendix shows that our main results are robust for using an alternative definition of an MNE buyer: firms with at least 100 employees and 50% foreign ownership. Appendix table A12 and A13 present similar results to Table 1, extending our analysis to supplying firms being part of a GVC. To capture indirect links to MNEs, we define a buyer firm as part of a GVC if a) it is MNE (with at least 500 employees an 10% foreign ownership), b) it is a direct supplier of MNEs (with at least 20 employees and at least 50% of VAT sales going to MNEs in the country), or c) it is exporting intermediate inputs to GVCs (with at least 20 employees and at least 50% of total sales coming from intermediate input exports in each year over the three year period (t-1,t+1). Table A12 shows that we get similar patterns as before, suppliers with external AIS technologies are more likely to serve firms being part of a GVC. Table **??** shows explicitly that firms having external AIS technologies are more likely to supply both MNEs and MNE suppliers, and the coefficient of the interaction term with the latter is about 75% of the former.

5.2 Type of new partners

Table 4 shows regressions focusing on actual link formation, the composition of new buyers, based on regression Equation (12). In these regressions the dependent variable is the (sales-weighted) share of MNEs among the firm's new buyers, acquired after 2015. Our variables of interest measure the supplier's technology use in 2015.

The dependent variable is the share of MNE buyers among the supplier's new buyers. We find evidence that suppliers who use external AIS technologies are more likely to acquire new MNE buyers: the share of MNEs in new buyers is 12 pp more for suppliers using both external AIS technologies compared to those which do not use such technologies. We don't find a significant effect for internal AIS and general ICT usage, showing that automated information sharing within the supply chain is a technology specifically favoured by MNE buyers.

In the regressions we control for a number of features. First, we control for industry dummies to make sure that our results are not driven by industry differences in the share of multinationals in potential buyers. Second, more productive/larger firms may have other features that are complementary with MNE technology. To alleviate this problem, we control for suppliers' number of employees, number of buyers and productivity. As expected, larger firms have more MNE buyers. Finally, our results are also robust to controlling for the initial share of MNE buyers, a proxy for μ_i.

In Table 5, which has the same structure as Table 4, we investigate the complementarity between the two firms' specific technologies. We replace the dependent variable with the average external AIS index of new buyers, measuring the share of new buyers which share information automatically with other firms. We find a positive relationship between suppliers' initial external AIS use and the average external AIS use of new buyers. Firms which share information automatically with other firms are more likely to form links with buyers who also share information via these systems. This relationship is specific to external AIS technologies, and we don't find similar patterns with internal AIS and generic ICT use.

5.3 Introduction of ICT

Table 6 investigates whether firms with specific types of buyers are more likely to introduce automated information sharing technologies. The dependent variable shows whether the firm introduced a technology after 2015 while the variables of interest are the type of buyers and their ICT technologies in 2015.[20]

Columns (1)-(2) focus on the links between current MNE buyers and subsequent ICT introduction. In column (1), the dependent variable shows whether the supplier introduced automated information sharing within the supply chain after 2015 and in column (2) we look at the introduction of EDI use. Here our variable of interest is the (transaction value-weighted) share of MNEs among the supplier's buyers in 2015. We find that firms with a higher share of MNE buyers are more likely to introduce AIS of supply chain information or EDI. Indeed, a firm with only MNE buyers is 11.4 pp more likely to introduce AIS in the supply chain and 7.8 pp more likely to introduce EDI compared to a firm with no MNE buyers. In columns (3)-(4) we focus on introducing AIS in the supply chain, and our variables of interest show the (weighted) average AIS use of buyers in 2015. We find that suppliers with a larger share of buyers who share information automatically are more likely to introduce a technology which allows the automated sharing of supply chain information. Either using the specific technology or the external AIS index, we find a positive relationship, while this is not true for other ICT measures. This result suggests a strong complementarity between the two firms' supply chain information sharing technology. We don't find significant complementarity for EDI.

Proposition 2 in our model emphasizes that larger firms with more buyers have stronger incentives to introduce information technologies even if those technologies are not complementary to other firms' technologies. Therefore, we control for firm size and productivity in all regressions. We also control

[20] We only consider firms which reported that they did not use the technology in 2015 and submitted at least one survey with information on the use of the technology after 2015.

for 4-digit industry fixed effects to filter out industry heterogeneity in the incentives to introduce the technologies.

6 Conclusions

We have found that firms with external AIS information technologies are more likely to have and acquire multinational clients and that suppliers of such firms are more likely to introduce these technologies. This seems to reflect complementarities between suppliers' external AIS technologies and MNEs' technology in general. Suppliers' external AIS technologies may be complementary to several features of the technology used by MNEs, including better management, better inputs or more innovative products. We have also presented evidence in line with a particular complementarity between suppliers' and MNEs' external AIS systems.

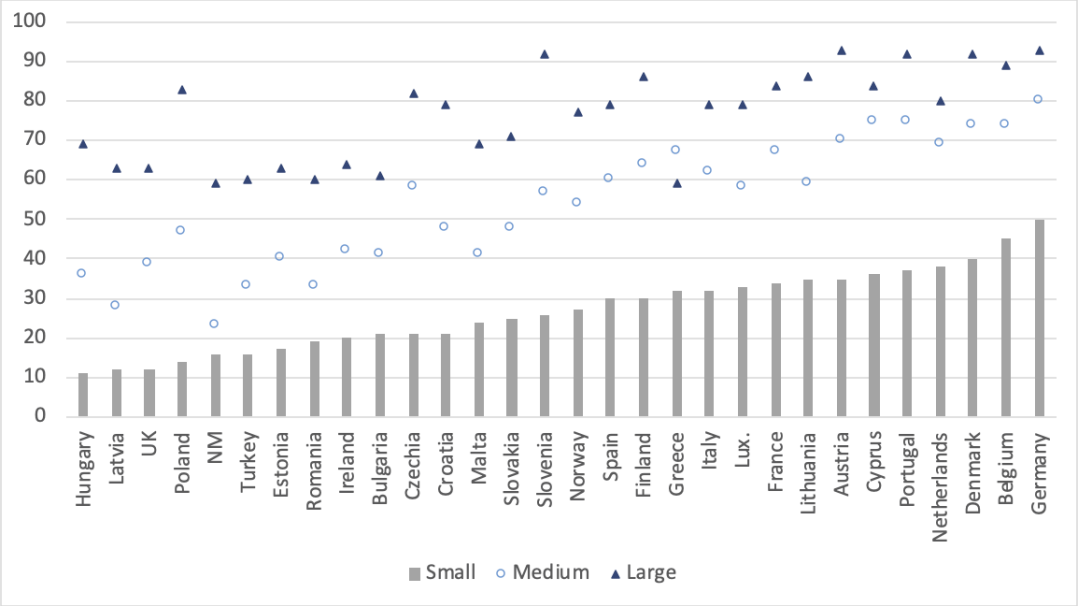
One consequence of this complementarity is that introducing external AIS technologies may promote supplier-MNE links directly, beyond the technologies' indirect effect via higher supplier productivity. The low prevalence of these technologies in European countries, especially among SMEs, suggests that these technologies may have high fixed costs. Link promotion policies may consider facilitating the introduction of these technologies.

The documented specific complementarity between the two firms' external AIS technologies also suggests that one firm's introduction of the technology may lead to propagation in the network. This mechanism suggests the presence of externalities and multiple equilibria in the network, again, providing a motivation for policy interventions.

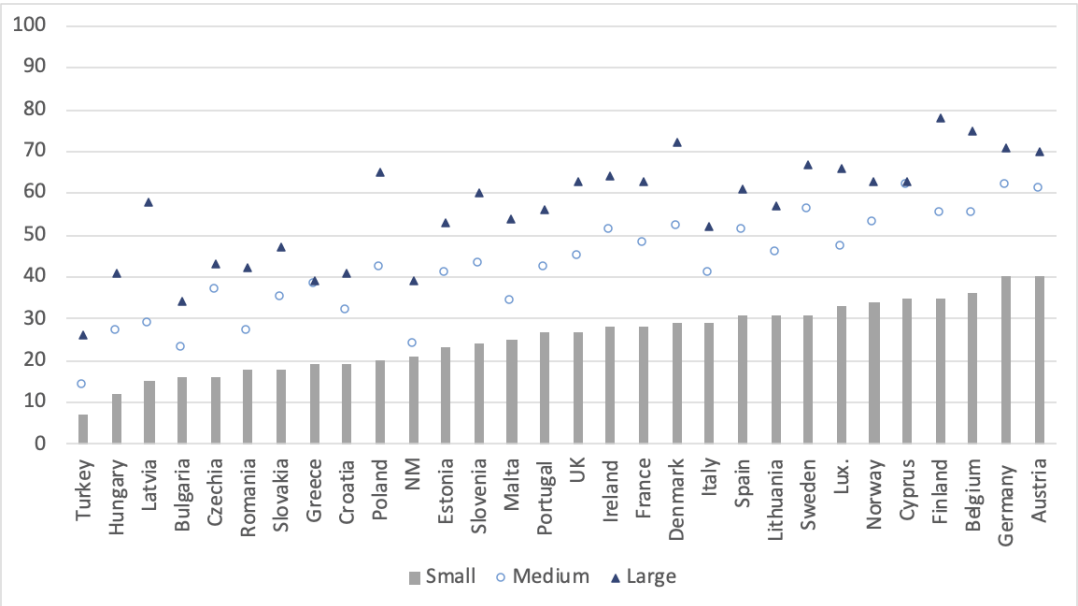
Figures

Figure 1: Prevalence of Automated Information Technologies (2015)

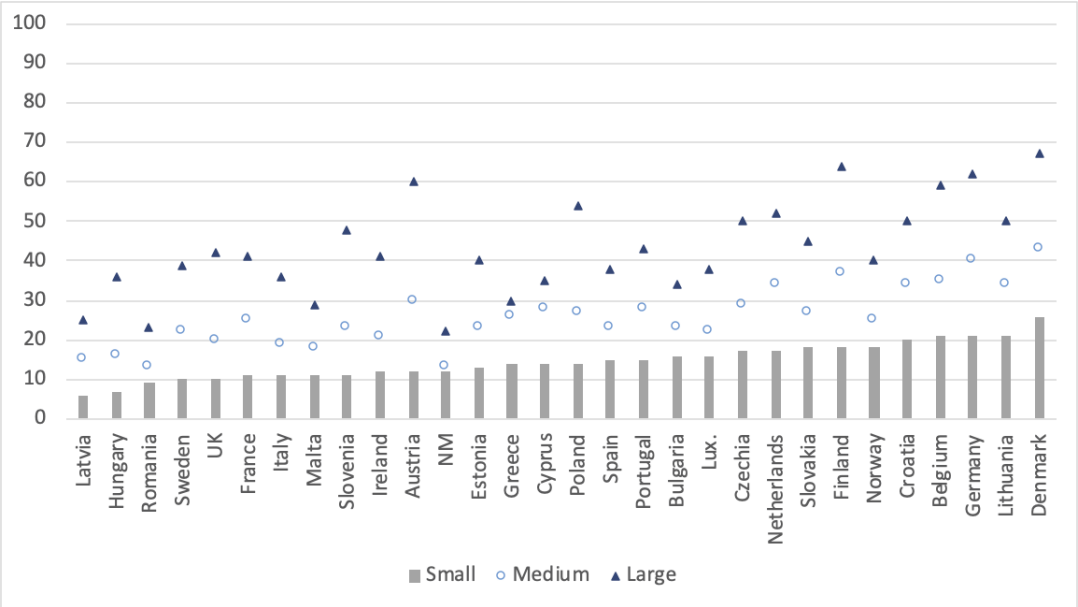
Panel A: Share of firms with ERP (%)



Panel B: Share of firms with CRM (%)

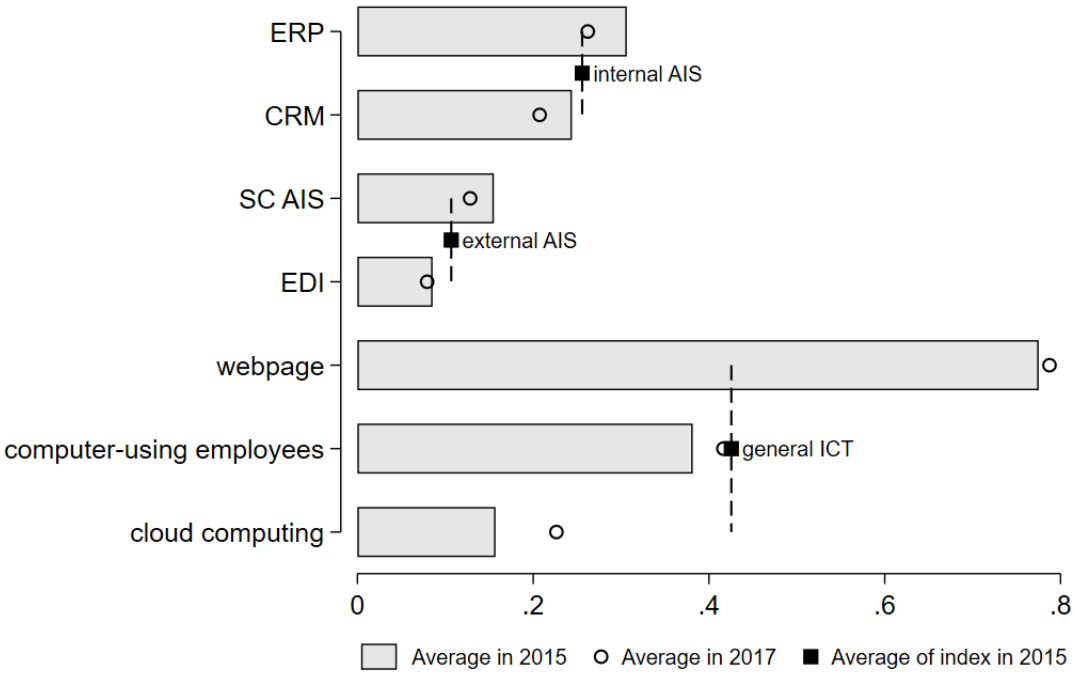


Panel C: Share of firms with automated information sharing in the supply chain(%)



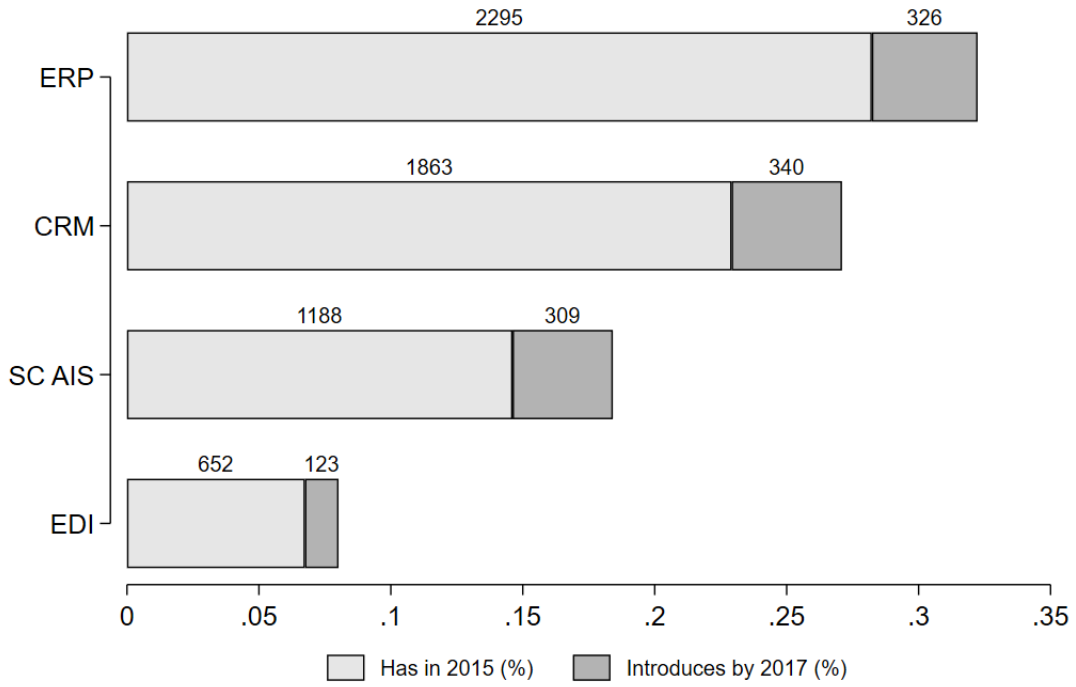
Note: This figure shows the share of firms reporting three types of automated information sharing technologies by country and firm size, based on the Eurostat's Enterprise ICT survey in 2015. Panel A shows the share of firms with Enterprise Resource Planning (ERP) systems, an example of which is SAP. Panel B shows firms with Customer Relationship Management (CRM) systems, an example for which is Salesforce. Panel C shows the share of firms who use automated systems to share information in their supply chains.

Figure 2: Average ICT values and indices



Note: ERP is Enterprise Resource Planning (an example SAP), CRM is Customer Relationship Management system (an example is Salesforce), SC AIS stands for Automated Information Sharing in the Supply Chain and EDI is electronic data interchange. Missing ICT variables are imputed with first lags or leads. Dashed lines connect the variables included in the index. All the variables are indicators, except from "computer-using employees", which shows a share.

Figure 3: Share of switchers from 2015 to 2017



Note: ERP is Enterprise Resource Planning (an example SAP), CRM is Customer Relationship Management system (an example is Salesforce), SC AIS stands for Automated Information Sharing in the Supply Chain and EDI is electronic data interchange. Missing ICT variables in 2015 are imputed with first lags or leads, no imputation is used for 2017. The height of bars corresponds to the share of ICT survey firms in 2015 having a technology or introducing it by 2017. The corresponding number of these firms is written on top of the columns.

Tables

Table 1: Link-level regressions: suppliers' technology and whether the buyer is an MNE

Dep.: supplier link	(1)	(2)
supplier AIS internal x buyer MNE	0.0180	
	(0.0994)	
supplier AIS external x buyer MNE		0.478***
		(0.102)
supplier ICT general x buyer MNE	0.0521	0.0764
	(0.169)	(0.136)
supplier no ICT data x buyer MNE	-0.0777	0.0449
	(0.102)	(0.0869)
supplier prod x buyer MNE	-0.0497	-0.0612*
	(0.0364)	(0.0336)
supplier AIS internal	0.128***	
	(0.0427)	
supplier AIS external		-0.103**
		(0.0454)
supplier ICT general	0.629***	0.599***
	(0.0703)	(0.0577)
supplier no ICT data	0.296***	0.242***
	(0.0430)	(0.0359)
supplier prod	-0.236	-0.161
	(0.161)	(0.152)
Choice FE	YES	YES
Supplier characteristics	YES	YES
Supplier x buyer characteristics	YES	YES
Observations	235,602	309,175

Note: This table reports cross section conditional logistic regressions from 2017 on the sample of potential buyer-supplier pairs where the dependent variable is whether there is actually a supplier-buyer link between the two firms and the question of interest is whether firms with different information systems are more likely to supply multinationals (MNE) (Equation (11)). We restrict the sample to pairs where both firms are operating in manufacturing. The main variables of interest are the interactions between the buyer's MNE status and the suppliers' information systems. MNE is a dummy taking the value of one if the buyer is foreign-owned and has at least 500 employees. 'AIS internal' proxies for automated information sharing or integration within the supplier firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firms automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the supplier's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. 'no ICT data' indicates if the we have no information of the supplier from the ICT database in 2017. Additional controls include supplier's size in log number of employees, interactions between supplier's and buyer's size and productivity, log distance and choice fixed effect. Standard errors, in parentheses, are clustered by buyer. Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 2: Link level regressions: Suppliers' and buyers' AIS

Dep.: supplier link	(1)	(2)
supplier AIS internal x buyer AIS internal	0.188	
	(0.118)	
supplier AIS external x buyer AIS external		0.404***
		(0.114)
supplier ICT general x buyer ICT general	0.587*	0.963***
	(0.333)	(0.250)
supplier no ICT data x buyer AIS internal	-0.220***	
	(0.0841)	
supplier productivity x buyer AIS internal	-0.0449	
	(0.0425)	
supplier no ICT data x buyer AIS external		-0.0154
		(0.0593)
supplier productivity x buyer AIS external		-0.0266
		(0.0367)
supplier AIS internal	0.0336	
	(0.0786)	
supplier AIS external		-0.110*
		(0.0639)
supplier ICT general	0.237	0.0768
	(0.195)	(0.148)
supplier no ICT data	0.208*	0.0276
	(0.119)	(0.0881)
supplier productivity	-0.442**	-0.257
	(0.218)	(0.183)
Supplier characteristics	YES	YES
Supplier x buyer characteristics	YES	YES
Choice FE	YES	YES
Observations	148,695	235,419

Note: This table reports cross section conditional logistic regressions from 2017 on the sample of all potential buyer-supplier pairs where the dependent variable is whether there is actually a supplier-buyer link between the two firms and the question of interest is whether firms with different information systems are more likely to supply buyers with specific information systems (Equation (11)). We restrict the sample to pairs where both firms are operating in manufacturing and the buyers submitted an ICT survey in 2017. The main variables of interest are the interactions between the buyer's information systems and the supplier's information systems. 'AIS internal' proxies for automated information sharing or integration within the firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firm's automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the firm's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. 'no ICT data' indicates if the we have no information of the supplier from the ICT database in 2017. Additional controls include supplier's size in log number of employees, interactions between supplier's and buyer's size and productivity, log distance, no ICT data of supplier x buyer ICT general and choice fixed effect. Standard errors, in parentheses, are clustered by buyer. Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 3: Link-level regressions: suppliers' technology and multiple buyer characteristics

Dep.: supplier link	(1)	(2)	(3)	(4)
supplier AIS internal x buyer MNE	0.159	0.153		
	(0.176)	(0.197)		
supplier AIS internal x buyer large	-0.212	-0.163		
	(0.134)	(0.156)		
supplier AIS internal x buyer foreign	-0.0114	-0.0683		
	(0.0946)	(0.125)		
supplier AIS internal x buyer productive	0.196**	0.0974		
	(0.0921)	(0.106)		
supplier AIS internal x buyer exporter		-0.184		
		(0.124)		
supplier AIS internal x buyer AIS internal		0.212		
		(0.134)		
supplier AIS external x buyer MNE			0.378**	0.466**
			(0.178)	(0.186)
supplier AIS external x buyer large			-0.0332	-0.204
			(0.134)	(0.152)
supplier AIS external x buyer foreign			0.151	0.0623
			(0.0994)	(0.117)
supplier AIS external x buyer productive			0.0783	0.0120
			(0.0965)	(0.102)
supplier AIS external x buyer exporter				0.0577
				(0.119)
supplier AIS external x buyer AIS external				0.324***
				(0.126)
Supplier characteristics	YES	YES	YES	YES
Supplier x buyer characteristics	YES	YES	YES	YES
Choice FE	YES	YES	YES	YES
Observations	235,602	148,731	309,175	235,890

Note: This table reports cross section conditional logistic regressions from 2017 on the sample of potential buyer-supplier pairs where the dependent variable is whether there is actually a supplier-buyer link between the two firms and the question of interest is whether firms with different information systems are more likely to supply firms with specific characteristics (Equation (11)). We restrict the sample to pairs where both firms are operating in manufacturing. The main variables of interest are the interactions between the buyer's characteristics and the suppliers' information systems. Buyer's characteristics include MNE (foreign-owned and has at least 500 employees), large (has at least 500 employees), foreign (has at least 20 employees and 10% foreign ownership share), productive (has at least 20 employees and is in the top productivity decile of the 2-digit industry), exporter (has at least 20 employees and and export sales are at least 10% of total sales in three subsequent years) and the AIS indicators of the buyer. 'AIS internal' proxies for automated information sharing or integration within the supplier firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firms automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the supplier's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. Additional controls include supplier's size in log number of employees, interactions between supplier's and buyer's size and productivity, log distance and choice fixed effect. Supplier characteristics include ICT indicators and productivity. Supplier-buyer characteristics include supplier's 'ICT general', no ICT data indicator and productivity interacted with all the buyer characteristics. Standard errors, in parentheses, are clustered by buyer. Significance levels are: $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

Table 4: Suppliers' initial technology and share of MNEs among new buyers

Dep.: MNE share	(1)	(2)	(3)	(4)
supplier AIS internal	0.0357			0.0364
	(0.0270)			(0.0320)
supplier AIS external		0.123***	0.123***	0.116**
		(0.0420)	(0.0453)	(0.0479)
supplier ICT general	0.121**	0.0875	0.0888	0.0994
	(0.0598)	(0.0532)	(0.0639)	(0.0763)
initial MNE share			0.0638**	0.0570*
			(0.0268)	(0.0291)
supplier ln # employees	0.0382***	0.0265***	0.0301***	0.0334***
	(0.0118)	(0.00925)	(0.0105)	(0.0117)
supplier productivity	0.0136	0.0175	0.0122	0.00140
	(0.0152)	(0.0140)	(0.0158)	(0.0171)
supplier ln # buyers	-0.0121	-0.0110	-0.0107	-0.00681
	(0.0177)	(0.0161)	(0.0163)	(0.0166)
Supplier in FE	yes	yes	yes	yes
Observations	996	1,132	956	848
R-squared	0.280	0.273	0.265	0.287

Note: This table shows how the information systems used in 2015 by a firm are related to the composition of the firm's new buyers acquired between 2016-2018 (see Equation (12)). The dependent variable shows the share of MNE firms (defined as foreign-owned firms with at least 500 employees) among the supplier's new buyers, weighted by the value of transactions. The sample includes manufacturing firms, while new buyers are defined as manufacturing firms which purchased from the supplier after 2015 for the first time, at least for 2 consecutive years, and were responsible for at least 1 percent of the supplier's sales. 'AIS internal' proxies for automated information sharing or integration within the firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firm's automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the firm's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. Initial MNE share stands for the weighted share of MNE buyers in 2015. All regressions include 4-digit industry fixed effects, based on the supplier's industry. Standard errors, in parentheses, are clustered by 4-digit supplier industry. Significance levels are: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 5: Suppliers' initial technology and average external AIS index of new buyers

Dep.: average ext AIS	(1)	(2)	(3)	(4)
supplier AIS internal	-0.00209			0.0319
	(0.0450)			(0.0537)
supplier AIS external		0.114**	0.125**	0.125**
		(0.0455)	(0.0517)	(0.0537)
supplier ICT general	0.0365	0.00999	0.00304	-0.00489
	(0.0647)	(0.0649)	(0.0772)	(0.0820)
initial average ext AIS			0.168***	0.189***
			(0.0447)	(0.0457)
supplier ln # employees	0.0209	0.00745	0.00244	-0.00362
	(0.0133)	(0.0126)	(0.0130)	(0.0145)
supplier productivity	0.00400	0.00578	0.0134	0.00892
	(0.0192)	(0.0181)	(0.0222)	(0.0219)
supplier ln # buyers	0.00577	0.00922	0.0101	0.00172
	(0.0180)	(0.0159)	(0.0205)	(0.0214)
Supplier in FE	yes	yes	yes	yes
Observations	833	946	740	653
R-squared	0.168	0.160	0.187	0.198

Note: This table shows how the information systems used in 2015 by a firm are related to the composition of the firm's new buyers acquired between 2016-2018 (see Equation (12). The dependent variable is the (transaction value weighted) average external automated information sharing (AIS) index of new buyers. The sample includes manufacturing firms, while new buyers are defined as manufacturing firms which purchased from the supplier after 2015 for the first time, at least for 2 consecutive years, and were responsible for at least 1 percent of the supplier's sales. 'AIS internal' proxies for automated information sharing or integration within the firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firm's automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the firm's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. Initial average external AIS stands for the weighted average external AIS index of buyers in 2015. All regressions include 4-digit industry fixed effects, based on the supplier's industry. Standard errors, in parentheses, are clustered by 4-digit supplier industry. Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 6: Buyers' characteristics and introduction of new technologies

Dep.:	(1) SC AIS	(2) EDI	(3) SC AIS	(4) SC AIS
share of MNE buyers	0.114**	0.0776***		
	(0.0445)	(0.0251)		
average int AIS of buyers			-0.0535	
			(0.0444)	
average ext AIS of buyers			0.132***	
			(0.0433)	
average general ICT of buyers			0.0167	
			(0.0667)	
sh. of buyers with SC AIS				0.121***
				(0.0358)
supplier ln # employees	0.0481***	0.0200***	0.0492***	0.0485***
	(0.0102)	(0.00667)	(0.0111)	(0.0110)
supplier prod	0.0340***	0.0293***	0.0416**	0.0430**
	(0.0126)	(0.0109)	(0.0198)	(0.0195)
supplier ln # buyers	0.0124	0.000722	0.00503	0.00562
	(0.0160)	(0.00861)	(0.0183)	(0.0182)
Supplier ind. FE	yes	yes	yes	yes
Observations	756	902	672	674
R-squared	0.214	0.207	0.225	0.227
Baseline prob of switching	4.45%	1.37%	4.45%	4.45%

Note: This table reports regressions which investigate how the composition of a firms buyers in 2015 is related to whether it introduces new external automated information sharing technologies after 2015 (Equation (13)). In columns (1), (3)-(4), the dependent variables is a dummy showing whether the firm introduced a system for sharing supply chain information automatically with with suppliers and buyers (SC AIS), while in column (2), the dependent variable is a dummy showing whether the firm introduced Electronic Data Interchange (EDI) technology. The sample consists of all manufacturing firms which reported in 2015 that they do not have SC AIS/EDI, and did submit an ICT survey with information about these technologies afterwards. The main explanatory variables measure the firm's buyers' characteristics in 2015: the (transaction value weighted) share of MNEs (defined as foreign-owned firms with at least 500 employees) among the supplier's buyers, the (transaction value weighted) average internal and external AIS index and general ICT index of buyers and the weighted share of buyers with SC AIS in 2015. 'AIS internal' proxies for automated information sharing or integration within the firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firm's automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the firm's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. All regressions include 4-digit industry fixed effects, based on the supplier's industry. Standard errors, in parentheses, are clustered by 4-digit supplier industry. Significance levels are: $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

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A Data Appendix

This section presents further descriptive patterns connected to our main variables. Table A1 presents the main descriptive statistics for the ICT variables we use with and without imputations in 2015 and 2017. It shows that imputing missing values with first lags and leads increases considerably the number of observations (with 25-54%), while the mean values decrease with 0-3 percentage points. As larger firms are present in the survey in more waves[21] and ICTs are also more prevalent in large firms (see A2), imputation increases the share of small firms in our dataset, leading to the observed decrease in averages. Gains in the number of observations are lower for ERP, CRM and SC AIS (even non-existing in 2017), as these are not included in the questionnaire in 2016 and 2018.

[21] Due to the sampling rules, coverage is higher among the larger firms, which are consequently included longer in the ICT survey: 48% of the largest firms having at least 500 employees are missing from the 12-year survey at most in one year, while 42% of the firms having 20-100 employees is present in the survey at most in 2 years.

Table A1: ICT variable patterns and the impact of imputation

	Raw			Imputed		
	N.obs	Mean	St.Dev.	N.obs	Mean	St.Dev.
Year=2015						
ERP	6486	0.31	0.46	8130	0.28	0.45
CRM	6486	0.24	0.43	8130	0.23	0.42
SC AIS	6486	0.16	0.36	8130	0.15	0.35
EDI	6486	0.09	0.28	9666	0.07	0.25
webpage	6382	0.78	0.42	9507	0.75	0.43
cloud	6382	0.16	0.36	9507	0.15	0.35
comp/emp	6382	0.38	0.31	9788	0.38	0.32
Year=2017						
ERP	6398	0.26	0.44	6398	0.26	0.44
CRM	6398	0.21	0.41	6398	0.21	0.41
SC AIS	6398	0.13	0.33	6398	0.13	0.33
EDI	6398	0.08	0.27	9881	0.07	0.25
webpage	6315	0.79	0.41	9734	0.77	0.42
cloud	6315	0.23	0.42	9734	0.22	0.41
comp/emp	6264	0.42	0.33	9668	0.42	0.33

Note: The table shows the number of observations, averages and standard deviations of ICT variables in 2015 and 2017. The left panel presents raw data and the right panel shows imputed data in which missing data are replaced with first lags or leads. ERP is Enterprise Resource Planning (an example SAP), CRM is Customer Relationship Management system (an example is Salesforce), SC AIS stands for Automated Information Sharing in the Supply Chain, EDI is electronic data interchange and cloud stands for cloud computing and comp/emp is the share of employees using a computer.

Table A2 presents descriptive statistics of the three ICT indices we use: internal AIS, external AIS and general ICT. Consistent with Table A1, it shows how the number of observations increases when we use the imputation, slightly decreasing the averages. Our additional imputation in the right panel – imputing yearly averages of a variable when only some but not all of the variables are missing for an index – adds further observations without changing the averages, but leaves the internal AIS unaffected, as all its elements are missing from the 2016 and 2018 survey.

Table A2: ICT index patterns and the impact of imputation

	Raw			Imputed			Additional imputation		
	N.obs	Mean	St.Dev.	N.obs	Mean	St.Dev.	N.obs	Mean	St.Dev.
Year=2015									
Internal AIS	6486	0.28	0.38	8130	0.26	0.37	8130	0.26	0.37
External AIS	6486	0.12	0.27	8130	0.11	0.26	9666	0.11	0.24
General ICT	6382	0.44	0.25	9506	0.43	0.26	9789	0.43	0.25
Year=2017									
Internal AIS	6398	0.23	0.36	6398	0.23	0.36	6398	0.23	0.36
External AIS	6398	0.10	0.25	6398	0.10	0.25	9881	0.10	0.21
General ICT	6315	0.48	0.27	9668	0.47	0.27	9734	0.47	0.27

Note: The table shows the number of observations, averages and standard deviations of the three indices we create in 2015 and 2017. The left panel presents indices calculated with raw data. The central panel shows indices based on imputed data in which missing data are replaced with first lags or leads. The right panel shows indices based on imputed data and using further imputations, replacing a missing element with the yearly average if not all the elements of the index are missing. Internal AIS includes ERP and CRM, external AIS includes Automated Information Sharing in the Supply Chain and EDI, and the General ICT index includes webpage, the share of computer-using employees and cloud computing.

Table A3 shows the overlap between different ICT-s in the full ICT database (2007-2018) , using non-imputed data. The cells show the percentage of observations having an ICT included in the row from all those observations which have an ICT included in the column conditional on also having information on the ICT included in the row. As an example, the second row of the first column shows that 48% of all those observations in which the firm has an ERP and we know about whether it has a CRM or not, the firm also has a CRM. The last column presents the share of ICT-s in the full sample. The coloring corresponds to a heat map, to make it easier having an overview. Clearly the most diffused ICT is webpage use with only slight differences across the groups having other specific technologies. Beyond that, there is only moderate or overlap between the various ICTs. A general pattern is clearly visible: all ICTs are use used by those firms which use any other technology–except for the highly widespread website–more frequently than in the overall sample. The strongest co-occurrence is between ERP and CRM: 48-59% in both directions. Similarly, EDI is the most frequent for firms

using automated information sharing in the supply chain, and vica versa. These patterns provide a further support for the way we create our internal and external AIS indices.

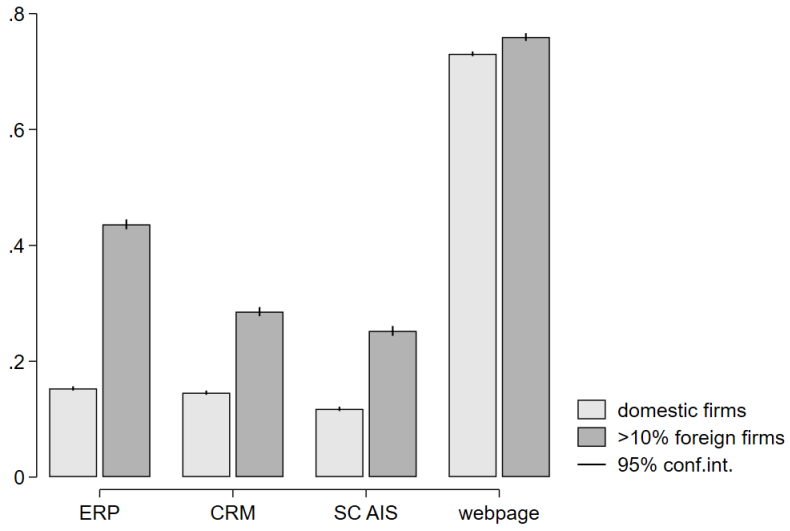
Table A3: Overlap between different ICT-s

	Sample: firms having a specific ICT						Overall
Share with	ERP	CRM	SC AIS	EDI	webpage	cloud	average
ERP	100%	59%	46%	67%	27%	49%	22%
CRM	48%	100%	37%	39%	23%	47%	18%
SC AIS	31%	31%	100%	58%	18%	27%	15%
EDI	19%	14%	31%	100%	9%	14%	8%
webpage	87%	92%	84%	87%	100%	90%	74%
cloud	28%	33%	30%	32%	22%	100%	19%

Note: The cells show the share of observations in the ICT dataset (2007-2018) in which a firm having an ICT presented in the column also had another ICT presented in the row. In each column 100% is all those observations in which the firm had the specific ICT of the column. ERP is Enterprise Resource Planning (an example SAP), CRM is Customer Relationship Management system (an example is Salesforce), SC AIS stands for Automated Information Sharing in the Supply Chain, EDI is electronic data interchange and cloud stands for cloud computing. The last column presents overall ICT shares in the full sample. The coloring corresponds to a heat map based on the overlap between the different ICTs.

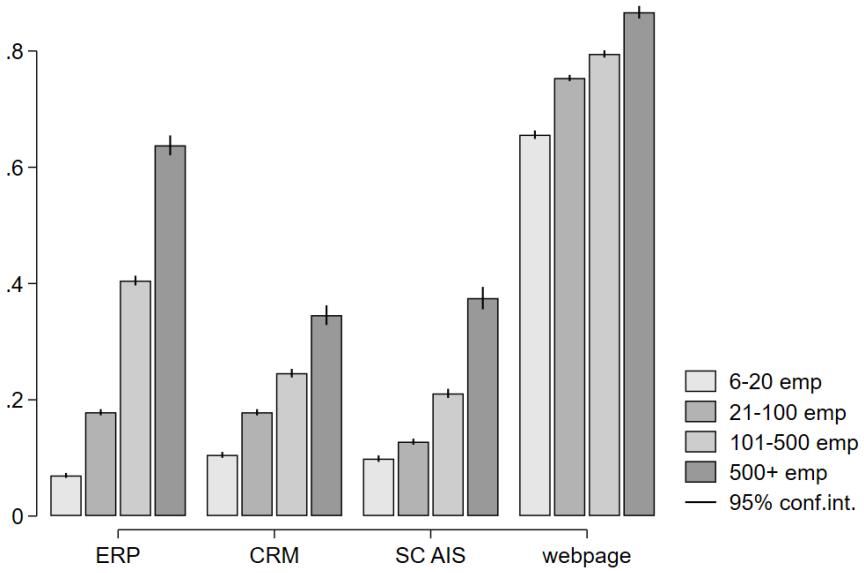
Figures A1-A2 show the prevalence of different technologies by firm characteristics. We can see that larger firms and foreign firms use all ICTs with a higher probability. The differences are the biggest for ERP and the smallest for webpage. These patterns are in line with a larger prevalence of ICTs among the MNE buyers.

Figure A1: Share of ICT by firm ownership



Note: The bars show the share of specific ICTs (non-imputed) in the full ICT dataset (2007-2018), separately for domestic and foreign-owned (at least 10%) firms. Lines at the top of the bars refer to the 95% confidence intervals. ERP is Enterprise Resource Planning (an example SAP), CRM is Customer Relationship Management system (an example is Salesforce) and SC AIS stands for Automated Information Sharing in the Supply Chain.

Figure A2: Share of ICT by firm size



Note: The bars show the share of specific ICTs (non-imputed) in the full ICT dataset (2007-2018), separately by size groups. Lines at the top of the bars refer to the 95% confidence intervals. ERP is Enterprise Resource Planning (an example SAP), CRM is Customer Relationship Management system (an example is Salesforce) and SC AIS stands for Automated Information Sharing in the Supply Chain.

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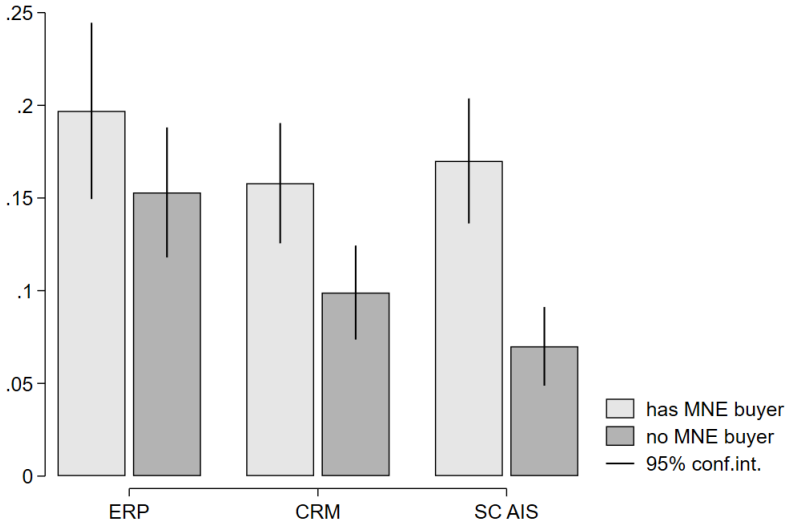
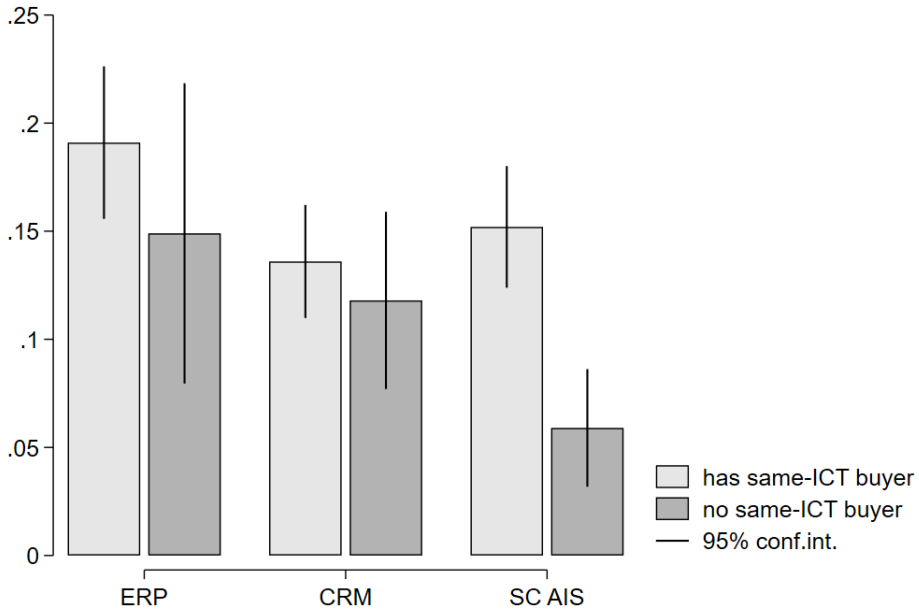
Figure A3: Share of switchers from 2015 to 2017 by MNE buyer



Note: The bars show the share of firms adopting a specific ICT by 2017 among those which did not have it in 2014-2015, grouped by whether the firm had an MNE buyer in 2015 or not. Lines at the top of the bars refer to the 95% confidence intervals. ERP is Enterprise Resource Planning (an example SAP), CRM is Customer Relationship Management system (an example is Salesforce) and SC AIS stands for Automated Information Sharing in the Supply Chain.

Figures A3-A4 show the share of firms introducing a specific ICT by 2017 among those firms which did not have it in 2015, by different firm groups. Groupings are based on the whether the firm has an MNE buyer or a buyer which already uses the same technology in 2015. Data patterns suggest that firms with MNE buyers or with same-ICT buyers adopt an ICT with a higher probability, and the difference is the highest for AIC in the supply chain.

Figure A4: Share of switchers from 2015 to 2017 by same-ICT buyer



Note: The bars show the share of firms adopting a specific ICT by 2017 among those which did not have it in 2014-2015, grouped by whether the firm had a buyer using the same technology in 2015 or not. Lines at the top of the bars refer to the 95% confidence intervals. ERP is Enterprise Resource Planning (an example SAP), CRM is Customer Relationship Management system (an example is Salesforce) and SC AIS stands for Automated Information Sharing in the Supply Chain.

Tables A4- A6 present descriptive statistics on firm links in the VAT data. Table A4 shows the number and the average value of transactions we observe in each year. The first panel shows the raw data. As there was a change in coverage in 2018, lowering the value threshold of transactions included in the data, we drop links with a transaction value with the earlier higher threshold in the last two years. Additionally, we also drop those observations, in which no balance sheet information can be linked to a buyer or a supplier. Omitted transactions include registered purchases from firms not having a tax identifier in Hungary (e.g. Amazon). The middle panel shows descriptive statistics after these data cleaning steps. As in the empirical part we focus on manufacturing firms only, both on the supplier and on the buyer side, the right panel corresponds to the final narrow dataset we use.

Table A4: Number and average value (in 1000 HUF) of transactions in the VAT data

	All transactions			Harmonizing value threshold, excluding if no balance data			Only manufacturing firms		
Year	N.obs	Mean	St.Dev.	N.obs	Mean	St.Dev.	N.obs	Mean	St.Dev.
2015	423 438	80 168	1 269 603	263 160	80 201	1 070 561	19 400	128 926	1 073 001
2016	426 749	80 661	1 304 385	259 843	77 484	905 473	19 383	122 786	1 058 662
2017	536 800	91 375	5 399 174	256 519	83 307	1 134 140	19 838	125 258	894 672
2018	1 519 352	28 140	823 752	695 725	36 929	756 220	46 860	70 821	1 838 842
2019	1 903 141	22 410	1 115 968	843 930	29 875	525 194	55 484	49 330	643 070

Note: The table shows the number of observations, averages and standard deviations of the three indices we create in 2015 and 2017. The left panel presents indices calculated with raw data. The central panel shows indices based on imputed data in which missing data are replaced with first lags or leads. The right panel shows indices based on imputed data and using further imputations, replacing a missing element with the yearly average if not all the elements of the index are missing. Internal AIS includes ERP and CRM, external AIS includes Automated Information Sharing in the Supply Chain and EDI, and the General ICT index includes webpage, the share of computer-using employees and cloud computing.

Table A5 shows the number of manufacturing buyers (column 1) and suppliers (column 2) in our cleaned data in year 2016. Column 3 is a subset of the second, containing only those suppliers which have data on ICT that year, which is 34-45% of all the suppliers. The first row includes all buyers, while the rows below include only MNE or specific ICT-using buyers for column 1, and suppliers having links with such buyers in columns 2-3. There are only few MNE buyers (3%), but 32% of suppliers have links to an MNE buyer. The share of ICT-using buyers is 7-17%, the ranking corresponding to the prevalence of the different ICTs in the ICT data. The share of suppliers having links to such buyers is again much higher, 38-64%. The share of suppliers with an MNE or an ICT-using buyer is even higher if we only consider those suppliers which are included in the ICT database.

The upper panel of Table A6 shows the average number of suppliers for a buyer. While an average buyer has about 5 suppliers, MNE buyers, which are much larger, have about 30.5 suppliers on average. The lower panel presents similar statistics concerning the average number of buyers for different supplier groups. An average supplier has about 4 buyers in our data. Suppliers in with data on ICT use have somewhat more, about 6.7 buyers on average, most of which also have ICT data (5.4 on average). Suppliers with specific ICT-s tend to have even more buyers, 8-11 on average.

Table A5: Number of buyers and suppliers in the VAT data in 2016 by type

Type of buyers	N. buyers	N. suppliers with buyer type	N. suppliers with ICT data & with buyer type
All	5776	6724	2292
MNE	160	2177	970
Has ERP	990	4323	1669
Has CRM	521	3021	1262
Has SC AIS	441	3048	1279
Has EDI	378	2584	1116

Note: The first column shows the number of buyers in our sample, by different characteristics (MNE status or ICT usage). The second column shows the number of suppliers having a specific type of buyer, and the third column shows the same but including only those suppliers which have ICT data that year.

Table A6: Number of partners per buyer or supplier in 2016 by type

Number of suppliers for a buyer

Sample	N.obs	Mean	St.dev
All buyers	5776	5.26	9.17
MNE buyers	160	30.45	24.51

Number of buyers for a supplier

Sample	N.obs	Mean	St.dev
All suppliers	6724	4.32	9.28
Suppliers with ICT data	2292	6.65	14.23
Both with ICT data	2051	5.44	10.95
Suppliers with ERP	892	9.74	20.91
Suppliers with CRM	479	11.29	24.05
Suppliers with SC AIS	387	9.80	20.43
Suppliers with EDI	337	8.09	15.25

Note: The upper panel presents the average number of suppliers for a buyer in the full sample and in the subsample of MNE buyers. The lower panel shows the average number of buyers for a supplier in the full sample, and in sub-samples of suppliers having data on ICT or using specific types of ICT. The last row contains the number of buyers with ICT data of those suppliers which also have data on ICT usage. ERP is Enterprise Resource Planning (an example SAP), CRM is Customer Relationship Management system (an example is Salesforce), SC AIS stands for Automated Information Sharing in the Supply Chain, EDI is electronic data interchange.

Table A7: Link-level linear probability regressions: suppliers' technology and whether the buyer is an MNE

Dep.: supplier link	(1)	(2)	(3)
supplier AIS internal x buyer MNE	0.00461***		0.00383***
	(0.00120)		(0.00118)
supplier AIS external x buyer MNE		0.00435**	0.00308*
		(0.00170)	(0.00169)
supplier ICT general x buyer MNE	0.00619***	0.00731***	0.00607***
	(0.00195)	(0.00197)	(0.00194)
ln distance	-0.00127***	-0.00127***	-0.00126***
	(6.13e-05)	(6.12e-05)	(6.13e-05)
supplier prod x buyer MNE	0.00122***	0.00138***	0.00104***
	(0.000382)	(0.000412)	(0.000388)
supplier prod. x buyer prod	0.000360***	0.000358***	0.000360***
	(6.34e-05)	(6.16e-05)	(6.34e-05)
Supplier FE	yes	yes	yes
Buyer FE	yes	yes	yes
Supplier ind-Buyer ind FE	yes	yes	yes
Observations	7,199,312	7,708,524	7,199,312
R-squared	0.037	0.036	0.037

Note: This table reports cross section linear probability regressions from 2017 on the sample of all potential buyer-supplier pairs. A potential buyer of a supplier firm i is defined as a firm which has ever had a supplier from the 4-digit industry of i. The dependent variable is whether there is actually a supplier-buyer link between the two firms and the question of interest is whether firms with different information systems are more likely to supply multinationals (MNE). We restrict the sample to pairs where both firms are operating in manufacturing. The main variables of interest are the interactions between the buyer's MNE status and the suppliers' information systems. MNE is a dummy taking the value of one if the buyer is foreign-owned and has at least 500 employees. 'AIS internal' proxies for automated information sharing or integration within the supplier firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firms automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the supplier's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. 4-digit NACE interaction dummies as well as buyer and supplier fixed effects are included in all regressions. Standard errors, in parentheses, are two-way clustered by supplier and buyer. Significance levels are: $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

Table A8: Link level linear probability regressions: Suppliers' and buyers' AIS

Dep.: supplier link	(1)	(2)	(3)	(4)
supplier AIS internal x buyer AIS internal	0.00233***	0.00184***		
	(0.000447)	(0.000403)		
supplier AIS external x buyer AIS external			0.00366***	0.00262***
			(0.000707)	(0.000713)
supplier ICT general x buyer ICT general	0.00551***	0.00445***	0.00559***	0.00437***
	(0.00125)	(0.00116)	(0.00123)	(0.00113)
ln distance	-0.00177***	-0.00177***	-0.00175***	-0.00174***
	(0.000110)	(0.000110)	(0.000106)	(0.000106)
supplier productivity x buyer AIS internal		0.000254*		
		(0.000131)		
supplier productivity x buyer AIS external				0.000827***
				(0.000225)
supplier prod. x buyer prod		0.000568***		0.000516***
		(0.000122)		(0.000111)
Supplier FE	yes	yes	yes	yes
Buyer FE	yes	yes	yes	yes
Supplier ind-Buyer ind FE	yes	yes	yes	yes
Observations	3,279,197	3,279,197	3,717,273	3,717,273
R-squared	0.050	0.050	0.047	0.048

Note: This table reports cross section linear probability regressions from 2017 on the sample of all potential buyer-supplier pairs. A potential buyer of a supplier firm i is defined as a firm which has ever had a supplier from the 4-digit industry of i. The dependent variable is whether there is actually a supplier-buyer link between the two firms and the question of interest is whether firms with different information systems are more likely to supply buyers with specific information systems (Equation (11)). We restrict the sample to pairs where both firms are operating in manufacturing and the buyers submitted an ICT survey in 2017. The main variables of interest are the interactions between the buyer's information systems and the supplier's information systems. 'AIS internal' proxies for automated information sharing or integration within the firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firm's automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the firm's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. 4-digit NACE interaction dummies as well as buyer and supplier fixed effects are included in all regressions. Standard errors, in parentheses, are two-way clustered by supplier and buyer. Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A9: Link-level regressions: suppliers' technology and whether the buyer is an MNE - separately for domestic and foreign suppliers

Dep.: supplier link	(1)	(2)
supplier AIS internal x buyer MNE	-0.00869	
	(0.124)	
supplier foreign & AIS internal x buyer MNE	-0.0489	
	(0.203)	
supplier AIS external x buyer MNE		0.352**
		(0.142)
supplier foreign & AIS external x buyer MNE		0.244
		(0.184)
supplier ICT general x buyer MNE	0.130	0.326**
	(0.218)	(0.164)
supplier foreign & ICT general x buyer MNE	-0.341	-0.738***
	(0.330)	(0.271)
supplier no ICT data x buyer MNE	-0.0446	0.128
	(0.120)	(0.0994)
supplier foreign & no ICT data x buyer MNE	-0.0778	-0.113
	(0.225)	(0.194)
supplier prod x buyer MNE	-0.0843**	-0.0902***
	(0.0368)	(0.0339)
supplier foreign	-0.873***	-0.693***
	(0.0943)	(0.0736)
supplier foreign x buyer MNE	0.398**	0.449***
	(0.201)	(0.166)
Supplier characteristics	YES	YES
Supplier x buyer characteristics	YES	YES
Choice FE	YES	YES
Observations	235,602	309,175

Note: This table reports cross section conditional logistic regressions from 2017 on the sample of potential buyer-supplier pairs where the dependent variable is whether there is actually a supplier-buyer link between the two firms and the question of interest is whether firms with different information systems are more likely to supply multinationals (MNE) (Equation (11)). We restrict the sample to pairs where both firms are operating in manufacturing. The main variables of interest are the interactions between the buyer's MNE status and the suppliers' information systems. All these variables are interacted with an indicator for the supplier being foreign-owned (at least in 10%). MNE is a dummy taking the value of one if the buyer is foreign-owned and has at least 500 employees. 'AIS internal' proxies for automated information sharing or integration within the supplier firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firms automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the supplier's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. 'no ICT data' indicates if the we have no information of the supplier from the ICT database in 2017. Additional controls include supplier's size in log number of employees, interactions between supplier's and buyer's size and productivity, log distance and choice fixed effect. Supplier characteristics include supplier ICT indicators and productivity, interacted with foreign status. Standard errors, in parentheses, are clustered by buyer. Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A10: Link level regressions: Suppliers' and buyers' AIS - - separately for domestic and foreign suppliers

Dep.: supplier link	(1)	(2)
supplier AIS internal x buyer AIS internal	0.0975	
	(0.142)	
supplier foreign & AIS internal x buyer AIS internal	0.219	
	(0.252)	
supplier AIS external x buyer AIS external		0.488***
		(0.164)
supplier foreign & AIS external x buyer AIS external		-0.273
		(0.215)
supplier ICT general x buyer ICT general	0.566	0.886***
	(0.415)	(0.299)
supplier foreign & ICT general x buyer ICT general	0.131	0.543
	(0.671)	(0.504)
supplier no ICT data x buyer AIS internal	-0.230**	
	(0.0913)	
supplier no ICT data x buyer AIS external		0.0283
		(0.0665)
supplier no ICT data x buyer ICT general	0.184	0.194
	(0.236)	(0.171)
supplier foreign	-0.569**	-0.288*
	(0.240)	(0.175)
Supplier characteristics	YES	YES
Supplier x buyer characteristics	YES	YES
Choice FE	YES	YES
Observations	148,695	235,419

Note: This table reports cross section conditional logistic regressions from 2017 on the sample of all potential buyer-supplier pairs where the dependent variable is whether there is actually a supplier-buyer link between the two firms and the question of interest is whether firms with different information systems are more likely to supply buyers with specific information systems (Equation (11)). We restrict the sample to pairs where both firms are operating in manufacturing and the buyers submitted an ICT survey in 2017. The main variables of interest are the interactions between the buyer's information systems and the supplier's information systems. All these variables are interacted with an indicator for the supplier being foreign-owned (at least in 10%). 'AIS internal' proxies for automated information sharing or integration within the firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firm's automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the firm's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. 'no ICT data' indicates if the we have no information of the supplier from the ICT database in 2017. Additional controls include supplier's size in log number of employees, interactions between supplier's and buyer's size and productivity, log distance, no ICT data of supplier x buyer ICT general and choice fixed effect. Additional controls include supplier's size in log number of employees, interactions between supplier's and buyer's size and productivity, log distance and choice fixed effect. Supplier characteristics include supplier ICT indicators and productivity, interacted with foreign status. Standard errors, in parentheses, are clustered by buyer. Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A11: Link-level regressions: suppliers' technology and whether the buyer is an MNE - alternative definition

Dep.: supplier link	(1)	(2)
supplier AIS internal x buyer MNE	0.0317	
	(0.0795)	
supplier AIS external x buyer MNE		0.388***
		(0.0826)
supplier ICT general x buyer MNE	0.174	0.0878
	(0.136)	(0.110)
supplier no ICT data x buyer MNE	-0.0598	-0.00889
	(0.0809)	(0.0684)
supplier prod x buyer MNE	-0.0513*	-0.0620**
	(0.0288)	(0.0263)
supplier AIS internal	0.120**	
	(0.0475)	
supplier AIS external		-0.145***
		(0.0504)
supplier ICT general	0.578***	0.583***
	(0.0784)	(0.0641)
supplier no ICT data	0.300***	0.252***
	(0.0473)	(0.0393)
supplier prod	-0.236	-0.169
	(0.162)	(0.152)
Choice FE	YES	YES
Supplier characteristics	YES	YES
Supplier x buyer characteristics	YES	YES
Observations	235,602	309,175

Note: This table reports cross section conditional logistic regressions from 2017 on the sample of potential buyer-supplier pairs where the dependent variable is whether there is actually a supplier-buyer link between the two firms and the question of interest is whether firms with different information systems are more likely to supply multinationals (MNE) (Equation (11)). We restrict the sample to pairs where both firms are operating in manufacturing. The main variables of interest are the interactions between the buyer's MNE status and the suppliers' information systems. MNE is a dummy taking the value of one if the buyer is majority foreign-owned and has at least 100 employees. 'AIS internal' proxies for automated information sharing or integration within the supplier firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firms automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the supplier's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. 'no ICT data' indicates if the we have no information of the supplier from the ICT database in 2017. Additional controls include supplier's size in log number of employees, interactions between supplier's and buyer's size and productivity, log distance and choice fixed effect. Standard errors, in parentheses, are clustered by buyer. Significance levels are: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table A12: Link-level regressions: suppliers' technology and whether the buyer is part of a GVC

Dep.: supplier link	(1)	(2)
supplier AIS internal x buyer GVC	0.00299	
	(0.0765)	
supplier AIS external x buyer GVC		0.317***
		(0.0792)
supplier ICT general x buyer GVC	0.226*	0.144
	(0.130)	(0.105)
supplier no ICT data x buyer GVC	0.0756	0.0822
	(0.0772)	(0.0648)
supplier prod x buyer GVC	-0.0660**	-0.0811***
	(0.0266)	(0.0243)
supplier AIS internal	0.131***	
	(0.0501)	
supplier AIS external		-0.148***
		(0.0544)
supplier ICT general	0.540***	0.553***
	(0.0848)	(0.0691)
supplier no ICT data	0.250***	0.217***
	(0.0503)	(0.0421)
supplier prod	-0.247	-0.184
	(0.161)	(0.151)
Supplier characteristics	YES	YES
Supplier x buyer characteristics	YES	YES
Choice FE	YES	YES
Observations	235,602	309,175

Note: This table reports cross section conditional logistic regressions from 2017 on the sample of potential buyer-supplier pairs where the dependent variable is whether there is actually a supplier-buyer link between the two firms and the question of interest is whether firms with different information systems are more likely to supply firms bein part of a GVC (GVC) (Equation (11)). We restrict the sample to pairs where both firms are operating in manufacturing. The main variables of interest are the interactions between the buyer's GVC status and the suppliers' information systems. GVC is a dummy taking the value of one if the buyer is an MNE (foreign-owned and has at least 500 employees) or it supplies MNEs within the country (at least 50% of VAT sales goes to MNEs). 'AIS internal' proxies for automated information sharing or integration within the supplier firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firms automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the supplier's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. 'no ICT data' indicates if the we have no information of the supplier from the ICT database in 2017. Additional controls include supplier's size in log number of employees, interactions between supplier's and buyer's size and productivity, log distance and choice fixed effect. Standard errors, in parentheses, are clustered by buyer. Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A13: Link-level regressions: suppliers' technology and whether the buyer is an MNE or an MNE supplier

Dep.: supplier link	(1)	(2)
supplier AIS internal x buyer MNE	0.0646	
	(0.101)	
supplier AIS internal x buyer MNE supplier	0.209*	
	(0.117)	
supplier AIS external x buyer MNE		0.535***
		(0.103)
supplier AIS external x buyer MNE supplier		0.396***
		(0.124)
supplier ICT general x buyer MNE	0.143	0.0276
	(0.119)	(0.0890)
supplier ICT general x buyer MNE supplier	0.324	0.176
	(0.197)	(0.166)
Supplier characteristics	YES	YES
Supplier x buyers characteristics	YES	YES
Choice FE	YES	YES
Observations	223,551	293,458

Note: This table reports cross section conditional logistic regressions from 2017 on the sample of potential buyer-supplier pairs where the dependent variable is whether there is actually a supplier-buyer link between the two firms and the question of interest is whether firms with different information systems are more likely to supply multinationals (MNE) (Equation (11)). We also allow for indirect links to multinationals, separately looking at the MNE supplier status of the buyer. We restrict the sample to pairs where both firms are operating in manufacturing. The main variables of interest are the interactions between the buyer's MNE or MNE supplier status and the suppliers' information systems. MNE is a dummy taking the value of one if the buyer is foreign-owned and has at least 500 employees. MNE supplier is a dummy taking the value of one if the buyer is a supplier of MNEs within the country (at least 50% of VAT sales go to MNEs). 'AIS internal' proxies for automated information sharing or integration within the supplier firm, and is created as an index from the ERP and CRM variables: Enterprise Resource Planning (ERP) systems, an example of which is SAP and Customer Relationship Management (CRM) systems, an example for which is Salesforce. 'AIS external' proxies for the firms automated information sharing with suppliers and buyers by creating an index from a variable showing whether the firm uses automated information sharing in its supply chain (SC AIS) and whether it uses electronic data interchange (EDI) technology. 'ICT general' is an index of the supplier's general ICT technology, created from three components: i) Number of computers/worker, ii) whether the firm has a webpage and iii) whether the firm uses cloud services. Additional controls include supplier's size in log number of employees, interactions between supplier's and buyer's size and productivity, log distance and choice fixed effect. Supplier characteristics include ICT indicators and productivity, supplier x buyer characteristics also include productivity and no ICT data indicator of supplier interacted with buyer's MNE or MNE supplier status. Standard errors, in parentheses, are clustered by buyer. Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.