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Productivity Spillovers through Linkages With Multinationals

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Productivity spillovers through linkages with multinationals

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Abstract

It is empirically well established that FDI vertical spillovers raise productivity levels of the firms in the host-country. Yet the main question is whether or not the spillovers are from multinational to domestic firms. This paper examines this question. We construct three alternative measures to relax the assumptions that are applied in the literature, while the standard measures are also employed in comparison. Using information on firm's sourcing and supplying behaviour, we find quantitative evidence that being the suppliers and the customers of multinationals increase the productivity. After controlling for the endogeneity of supplier status, we find that a 1 percent increase in backward linkage raises the productivity of domestic firms by about 0.2 percent, while a 1 percent increase in forward linkages raises firm productivity by about 1.7 percent to 2.3 percent. However, using standard measures we fail to find evidence for spillovers through vertical linkages.

Keywords: Forward Linkages, Backward Linkages, Multinational Firms, Firm Productivity
JEL classification: D22, F23, L22

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1 Introduction

Multinational firms have the potential to deliver substantial benefits to indigenous firms in the host-country. In the international economics literature, the productivity spillovers from inward forreign direct investment (henceforth, FDI) generally refer to the improved technology of domestic firms who access to the specialized varieties of resources from multinational firms(Haskel, Pereira, & Slaughter, 2007). A large body of empirical literature using firm level data sets has analysed the mechanisms behind this process. They generally confirm the benefits to firms productivity through supply inputs to multinationals, or purchase outputs from multinationals, i.e., through FDI vertical linkages (Javorcik, 2004; Gorodnichenko, Svejnar, & Terrell, 2014; Newman et al., 2015; Jude, 2016; Ciani & Imbruno, 2017).

Based on the well established literature, we would expect spillovers to exert gains on productivity from multinationals to domestic firms. However, we have little evidence on the direction of spillovers, as current measures of vertical linkages[1] are based upon host-country input-output matrixes. As noted byBarrios, Görg, and Strobl (2011), simply relying on input-output matrixes might not help researchers to identify the actual demand of inputs from multinationals and the supply of outputs to multinationals. Instead, it might only allow researchers to proxy the proportion of inputs or supplies that comes from or goes to the local firms. It implies the difficulty on identifying the direction of spillovers.

Meanwhile, by measuring linkages based on the input-output tables implies a number of assumptions. First, it assumes that the demand of inputs purchased by domestic firms downstream from multinationals upstream is same as the demand of inputs purchased by local firms downstream from local firms upstream (see for instance, Javorcik, 2004; Gorodnichenko et al., 2014; Newman et al., 2015). Second, it assumes that the supply of outputs from upstream domestic firms to downstream multinationals is same as the outputs sold from local firms upstream to local firms downstream. Thus, little is known whether or not multinational firms benefit domestic firms through the vertical linkages.

In this study, we fill these gaps by reconstructing measures on vertical linkages. First of all, we relax the assumption that domestic firms supply inputs to downstream multinationals the same proportion as local firms upstream to local firms downstream by using actual sales of domestic firm to multinationals. The backward linkage is therefore mea-

[1]The vertical linkages refer to domestic firms purchase inputs from upstream multinationals (forward linkages), or supply outputs to downstream multinationals (backward linkages). See Table 1 for the linkage definition.

sured at firm-level. This allows us to capture backward spillovers from multinationals to domestic firms. Secondly, we relax the assumption that domestic firms purchase inputs from upstream multinationals the same proportion as local firms upstream from local firms downstream to obtain the measure on forward linkages at firm-level. By using data on multinational firms' outputs to the large domestic firms across sectors conjecturing with domestic inputs of each firm, we proxy the proportion of inputs sourced from multinationals to each domestic firm. This measure allows forward spillovers to be captured from multinational to domestic firms. Thirdly, we experiment imported inputs as a proxy for the inputs purchased by domestic firm from multinationals. Comparing both measures of forward linkages allows us to observe the range of the magnitude on forward spillovers, as the true proportion of inputs sourced from multinationals to domestic firm would lie somewhere between them. The last point is that we replicate the estimations by using standard measures to see whether the measurement selection matters for capturing the spillovers.

The results confirm that the standard measures on both backward and forward linkages lead biased and overestimated spillover effects, and no empirical evidence for the linkage spillovers are found. In contrast, the two measures for forward linkages perform statistically well, and a range of magnitude on the estimated coefficients of forward linkages is observed. The firm-level backward measure also arguably is more able to capture spillovers from multinationals to domestic firms. By relaxing the assumptions we find that 1 percent increase in backward linkage raises the productivity of domestic firms by about 0.2 percent, while a 1 percent increase in forward linkages raises the productivity of domestic firms by about 1.7 percent to 2.3 percent. Our results are not sensitive to the potential biases including firm motivation, new technology acquisition, feedback effects, environment institution and supplier status.

The paper proceeds as follows. Section 2 provides an overview on recent FDI linkages literature. Section 3 outlines the empirical strategy, while section 4 describes the firm-level survey data. The empirical results and conclusions are presented in section 5 and section 6.

2 Literature Review

The first paper measuring productivity spillovers from multinationals to host-country firms was published by Javorcik (2004), who introduced the method of applying host country's input-output matrixes to calculate both forward and backward linkages. Javor-

cik's measures have been widely used in the empirical literature, as it is difficult to get actual sources and supplies of domestic firms. Thus, by applying host country's input-outputs matrixes could enable researchers to proxy the demand and supply chains among upstream and downstream firms.

2.1 The Measurement Matters

2.1.1 Different Sourcing and Supplying Behaviour Matter

Although several empirical studies using the measures of Javorcik with firm-level data to confirm such positive spillovers (e.g., Blalock & Gertler, 2008; Girma, Görg, & Pisu, 2008; Javorcik & Spatareanu, 2008; Newman et al., 2015; Jude, 2016), Barrios et al. (2011) suggest that taking input-output tables of host-country might lead biased estimate of spillovers. In fact, the measures of backward and forward linkages in Javorcik (2004) are fully dependent upon the assumptions that multinationals from different nationalities have the same inputs sourcing behaviour as the domestic firms in the host country. It also relies on the assumption that domestic firms source inputs from multinationals the same proportion as they source from the local operating firms.

Barrios et al. (2011) argue that these assumptions are easily violated. First, multinationals might have different level of technology and sourcing strategy compared to domestic firms. Thus, by assuming the same proportion of input sourcing behaviour among domestic and multinational firms would lead biases in the measurement. It is also not clear whether or not domestic firms would source the same amount of inputs from multinationals as they source from the local market. By focusing on the suppliers of multinationals, Barrios et al. (2011) conduct a measure incorporating input-output tables taken from each multinational firm's own country. The authors also extend their measure by taking multinational firms' domestic inputs instead of using foreign output share. By using plant-level data from Ireland, they are able to show that the choice of measures on backward linkage matters the empirical findings.

Nevertheless, their measures are not without limitation. It can be seen that these authors left some assumptions that might also affect the findings of vertical spillovers. First, using I-O tables taken from each multinational firms' own country might not mitigate the measurement bias found in Javorcik (2004). This is because multinationals might behave differently in the inputs sourcing or output supplying in the host-country compared to they do in their home country. Second, they assume that all local firms would source same input materials with the same proportion from multinationals, irrespective to how

different the technology of each firm in the host country would be. It can be argued that multinationals may source more inputs from other multinationals other than from the domestic firms due to the material quality the domestic firms can offer. If this is the case, then the evidence of spillover effects they found might be less proper to represent as the spillovers from multinationals to domestic firms.

2.1.2 Foreign Ownership Structure Matters

In fact, different structures of foreign ownership would also affect multinational firms' sourcing behaviour in the host-country. Javorcik and Spatareanu (2008) point out two hypotheses: (I) affiliates with joint domestic and foreign ownership may be more likely to engage in local sourcing than wholly owned foreign subsidiaries and (II) multinationals tend to transfer less sophisticated technologies to their partially owned affiliates than to wholly owned subsidiaries. By using a firm-level panel data from Romania through 1998-2003 period, their results confirm the two expectation. However, one limitation from this study is that it is still limited to get sourcing and supplying data for each firm at firm-level. Instead, the authors employ input-output tables to construct the measure of vertical linkages.

2.1.3 Worldwide Evidence

It can also be argued that prior studies are all based on a particular economy (see, for instance, Javorcik, 2004 for Lithuania; Javorcik & Spatareanu, 2008 for Romania; Barrios et al., 2011 for Ireland; Newman et al., 2015 for Vietnam), which may not represent as the general case worldwide. Gorodnichenko et al. (2014) take the advantage of using Word Bank Business Environment and Enterprise Performance Survey (BEEPS) dataset to explore the role of vertical spillovers in a cross-country context. Their analysis covers firms in both service and manufacturing industries in 17 transition economies. However, their results are limited as sector to sector, as the measures of spillovers still rely on input-output matrixes.

As described above, the limitation on the data and measures of vertical spillovers may potentially prevent researchers from identifying the direction of spillovers between multinationals and domestic firms.

2.2 Empirical Findings

2.2.1 Positive or Negative Spillovers?

The empirical findings of FDI spillovers in the literature are well established. Yet, researchers would either find the positive effect or produce evidence of negative spillovers on firm productivity. This reveals a fact that the differences in firm's sourcing and supplying behaviour play an important determinant.

Horizontal Spillovers

By focusing on horizontal spillovers, first of all, Barrios et al. (2011) who use Irish plant level data find positive but statistically insignificant effect of horizontal spillovers on firm's productivity, while Newman et al. (2015) find both positive and negative horizontal spillovers in Vietnam survey data, although insignificant. Javorcik (2004) uses firm-level data from Lithuania also find statistically insignificant and negative effects of horizontal spillovers on firm's productivity. On the other hand, by using Word Bank firm-level survey data, Gorodnichenko et al. (2014) find positive and statistically significant horizontal spillovers on firm's performance at 5% significance level when the observations only include service sector and old establishments.

In fact, the positive horizontal spillovers within sectors may arise when local firms "poach" workers from multinationals as well as adopting technolog (Newman et al., 2015). It may also occur if multinationals do not prevent their embodied technologies from being imitated and copied by the domestic competitors (Javorcik, 2004). In addition, spillovers may also differ with different market strategies (Javorcik & Spatareanu, 2008).

Backward Spillovers

Second, the backward linkage spillovers may occur when multinational firms downstream source inputs from domestic firms upstream.

Javorcik (2004) was among the first study to identify spillovers through vertical linkages. She finds that spillovers are more likely to occur when upstream domestic firms supply inputs to downstream multinationals, with 5% to 1% significance levels throughout 20 sectors in Lithuania. By using Republic of Indonesian's manufacturing data, Blalock and Gertler (2008) find evidence of productivity gains among domestic firms who supply downstream foreign firms across sectors.

On the other hand, Newman et al. (2015) confirm that supplying inputs to multinationals downstream does not generate such effects on domestic firm productivity. They

suggest that the backward spillovers cannot be captured unless foreign ownership structure is controlled for. This is because the different structures imply the different sourcing strategies, which would have different implications to firm performance. Xu and Sheng (2012), meanwhile, incorporate clustering errors by using Woodridge's two-stage procedure and find even negative and statistically significant effect of backward spillovers on Chinese manufacturing firms between 2000 and 2003. While Barrios et al. (2011) also confirm the negative effects of backward linkages, they find that the positive effects appear once they switch host-country input-output matrixes to foreign firms own home country matrixes.

As a matter of fact, it is possible that multinational firms may establish relationships with many different upstream suppliers to reduce the dependency on a single supplier (Blalock & Gertler, 2008). However, multinational firms may try to support their local suppliers in order to reduce input costs and increase the quality of the inputs supplied by the local firms. Given the benefit of lower-priced inputs, Pack and Saggi (2001) note that downstream multinationals would therefore increase the demand of the inputs from upstream firms and the stronger demand downstream would therefore increase the outputs of upstream firms, which would help the technology recipient in the upstream firms. The former would potentially generate a negative spillover to the domestic firms since multinationals may be expected to have stronger bargaining power than domestic companies, while the latter would likely raise the possibility of positive spillovers through backward linkages from foreign firms to domestic firms.

Forward Spillovers

Third, forward linkage spillovers occur when domestic firms purchase inputs from the upstream multinationals. As the input materials provided by the foreign firms may embody advanced technologies, domestic firms may benefit from this linkages (Grossman & Helpman, 1991). At the same time, other domestic firms downstream may also benefit from the spillovers if they copy these inputs purchased by the others. The spillovers may also occur if foreign firms supply inputs to the local firms accompanied by services and other supports including labour training and now-how provided (Javorcik, 2004). However, negative spillovers may occur if high competition from upstream forcing all downstream firms to eliminate inefficiencies in producing inputs purchased by the upstream multinationals (Newman et al., 2015).

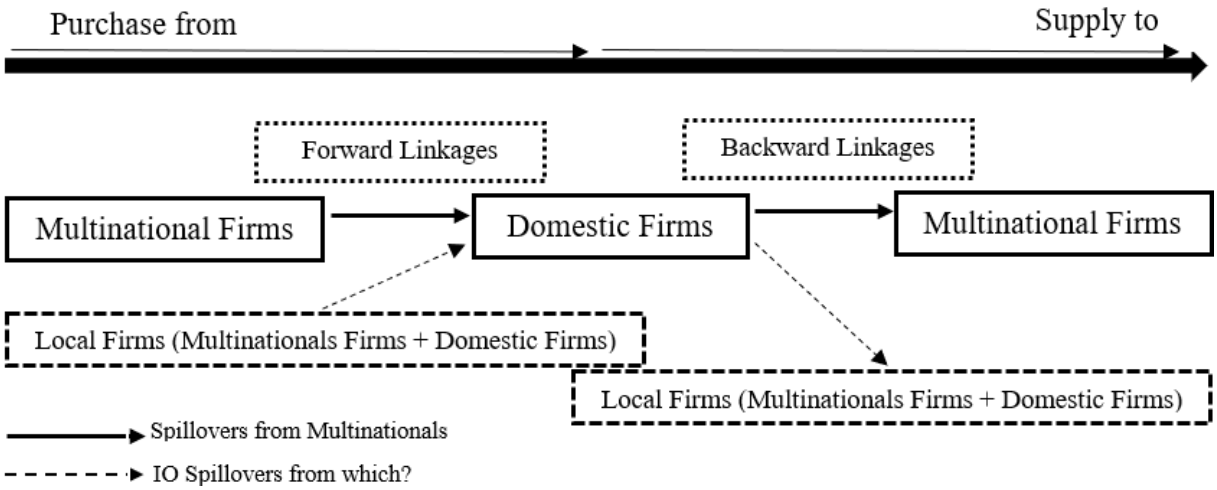

Fig 1. The Vertical FDI spillovers

2.3 Brief Summary

As the findings above are mixed, this would cast doubt in whether or not by using aggregated data captures spillover effects. It can be argued that different firms would source and supply differently, and these differences would not be accounted if aggregated data such as the data of input-output tables were applied.

We construct a clear structure of productivity spillovers in Figure 1 to demonstrate how the spillovers would be measured by the different data. It shows that there are two different ways that spillovers may be measured. First, by applying sector-level input-output data, both backward and forward spillovers would be estimated. However, since this measure overestimate the status of suppliers and customers of multinationals, it might lead to bias estimates. The second way is to use data of domestic firm sources and supplies that come from and go to the multinationals. As discussed, both ways would capture the spillovers, but the latter would be preferred. As the consequence of applying aggregated data, little is known whether or not the spillovers found in the literature are from multinationals to domestic firms.

To the best of our knowledge, there is only one study that relieve above measurement limitation. Görg and Seric (2016) use firm-level data on the domestic suppliers and customers of multinationals. They focus on the nexus in whether domestic firms receiving assistance from either the government or the multinationals strengthen the spillovers on domestic firm product innovation and labour productivity. Focusing on 19 Sub-Saharan African countries they confirm that while no impact from government support or help on product innovation and labour productivity, both supplying to and purchasing from multinationals are positively associated with product innovation and labour productivity.

Our study is related to Gorodnichenko et al. (2014) and Görg and Seric (2016). Nevertheless, our work differs in several aspects. We construct two indirect measures for forward linkages at firm-level based on the reported firm's sales that go to each downstream sector and the sales of multinationals go to large domestic firms. These data enable us to not rely on input-output tables. In addition, the measures we constructed are less restricted by the data limitation, which can be widely applied for further studies. While previous studies measure backward linkages at sector-level, we construct this measure at firm-level by taking actual data of domestic firm's supplies to the multinationals. This is an important aspect that is absent from above studies.

3 Estimation strategy

3.1 FDI Spillovers Measurement

The previous studies generally estimated horizontal spillovers by taking foreign sales as a ratio of total sales in a whole sector. The horizontal linkage is therefore constructed as follow

$$Horizontal_{jct} = \frac{\sum_i \rho_{ijct} Sales_{ijct}}{\sum_i Sales_{ijct}} \tag{1}$$

where ρ_{ijct} is the foreign ownership of firm i in country c sector j at time t, $Sales_{ijct}$ is the total sales of firm i in country c sector j at time t.

The standard measure on forward linkage was constructed by Javorcik (2004), in which she incorporated the input-output matrixes to collect information on the proportion of local inputs purchased by downstream domestic firms from upstream multinationals, and on the proportion of outputs sold from upstream domestic firms to downstream multinationals

$$Forward_{jt}^{IO} = \sum_d \delta_{dj}^{IO} H_{dt} \tag{2}$$

$$Backward_{jt}^{IO} = \sum_u \delta_{uj}^{IO} H_{ut} \tag{3}$$

were δ_{dj}^{IO} is the proportion of inputs in sector j purchased from sector d at time t, δ_{uj}^{IO} is the proportion of outputs sold from sector j to sector u. H_{ut} is the horizontal spillover at

each downstream sector u, while H_{dt} is the horizontal spillover at each upstream sector d.

These measures have been widely used in the literature, including Newman et al. (2015), Barrios et al. (2011) and Gorodnichenko et al. (2014)[2]. However, the measure on backward linkage was then improved by Barrios et al. (2011), in which the authors tried to use the total amount of inputs multinational sourced in the domestic economy

$$Backward_{jt}^{IO} = \sum_{u} \delta_{uj}^{Home} \frac{\sum_i M_{iut}^{D}}{\sum_i M_{ikt}} \tag{4}$$

were δ_{uj}^{Home} is the proportion of outputs sold from sector j to sector u at time t, M_{iut}^{D} refers to the material inputs that multinational sources in the downstream sector.

Although the measures in Eq.(2) and Eq.(3) have been intensively used in the literature, they may have some limitations. To be more specific, the measures require the following conditionals to be held:

A1. The outputs supplied from multinationals upstream to the domestic firms downstream is the same as it supplied by local firms upstream to local firms downstream; **A2**. The outputs supplied from domestic firms upstream to multinationals downstream is the same as the inputs sourced by local firms downstream from the local firms upstream.

First, it can be argued that multinationals would have different levels of technology compared with domestic firms, and so A1 and A2 are likely to be violated. Second, by holding A1, it assumes that domestic firms source inputs from multinationals upstream the same as they do from the local firms upstream. It implies the difficulty of identifying whether spillovers are coming from multinationals to domestic firms, as domestic firms downstream might source more from domestic firms other than multinationals. Third, holding A2 implies the difficulty of modelling how domestic firms would supply to the multinationals downstream. In fact, the measure of backward linkages proposed by Barrios et al. (2011) use "multinational local sources" to proxy "the supplies of multinationals from domestic firms" and then post another assumption to replace assumption A2:

Domestic firms upstream supply outputs to multinationals downstream the same proportion as multinationals downstream source inputs from local firms upstream.

Since this proportion only represents the supplies of multinationals from the local

[2]Note that Gorodnichenko et al. (2014) uses these measure at share not at level

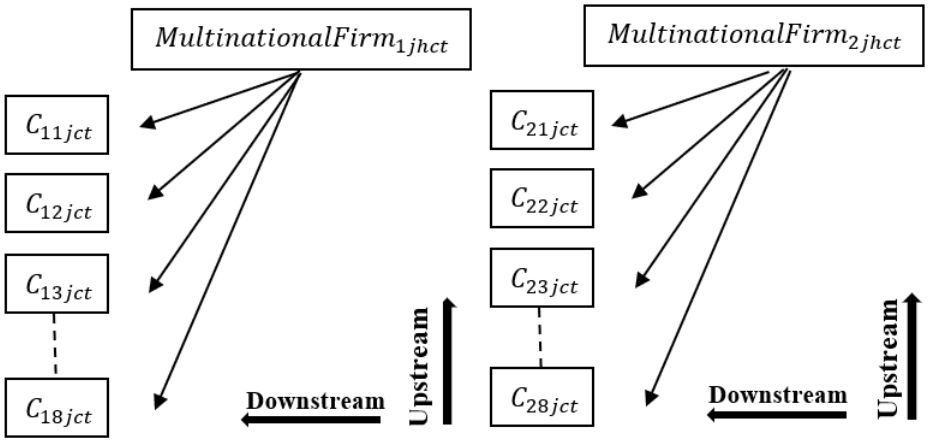

Fig. 2. An example of the calculation of downstream sector input sources from upstream multinationals.

firms (multinationals plus domestic firms), combining this with IO coefficients would still not be able to identify the direction of backward spillovers.

To relax assumption A1, it requires data on domestic firm's inputs sourced from multinationals upstream. Unfortunately, this data is unavailable. However, as the BEEPS provides information on "What proportion of your sales comes from the following sectors in which your establishment operates?" and "What proportion of your domestic sales goes to the large domestic firms (those with approximately 250 plus workers and not including your parent company)", we take these data conjugating with firm's domestically purchased inputs. We proxy the inputs of domestic firms downstream supplied by multinationals upstream by the above information.

We first construct the proportion of inputs sold by each multinational to 8 given downstream sectors[3] (also see Fig. 2., for example)

$$c_{mjhct} = \frac{MultinationalSold_{mjhct}}{TotalMultinationalSold_{mjct}}, for h = 1, 2, 3, ...8 \tag{5}$$

where $MultinationalSold_{mjhct}$ is the outputs sold by each multinational m in country c upstream sector j to downstream sector h at time t. Then, by using Eqs. 5 the proxy for

[3]The BEEPS survey waves 2002, 2003 and 2005 only provide firm information based on the 8 sectors. They are Mining and Quarrying; Constructing; Manufacturing; Transport and Storage; Wholesale, Retail trade and Repair of motor vehicles; Real estate; Hotel, Restaurant; Otherwise. See data section for more information

forward linkage is defined as

$$Forward_{ijct}^{proxy-buy} = \sum_{h}\sum_{m} c_{mjhct} \frac{\sum_j \sum_m MultinationalSold_{mjct}^{LD}}{\sum_j \sum_m TotalMultinationalSold_{mjct}} \mu_{ijct}, \quad forh = 1, 2, 3, ...8 \tag{6}$$

where c_{mjhct} is the proportion of multinational firms in sector j inputs purchased by downstream sector h (i.e., $c_{1,jct}$, $c_{2,jct}$,..., $c_{8,jct}$), and $MultinationalSold_{ct}^{LD}/TotalMultinationalSold_{ct}$ is the proportion for the sales of multinationals to the large domestic firms across countries. μ_{ijct} is the proportion of total inputs source domestically of firm i in sector j country c at time t. We therefore obtain the measure of forward linkages at firm-level. It represents the proportion of inputs sold by multinationals to sector j in country c that is going to firm i.

The measure proposed in Eq (6) lets us investigate how assumption A1 would affect forward spillovers. Note that as this is a proxy that tries to approximate the actual purchased inputs of domestic firm from multinationals, three assumptions are required. First, We assume that domestic firms purchase inputs from multinationals the same proportion of large domestic firms. Second, large domestic firms purchase from multinational firms the same across countries. Third, domestic firm purchase inputs from multinational firms the same as they purchase from local firms.

We also relax assumption A1 by using domestic firm's imported inputs. It is likely that domestic firm would source the same proportion of total inputs from multinationals upstream as that of imported inputs. We calculate the forward linkages by using imported inputs as follow

$$Forward_{ijct}^{proxy-imp} = \sum_{h}\sum_{m} c_{mjhct} \frac{\sum_j \sum_m MultinationalSold_{mjct}^{LD}}{\sum_j \sum_m TotalMultinationalSold_{mjct}} \frac{m_{ijct}^{imported}}{m_{ijct}} \tag{7}$$

where $m_{ijct}^{imported}$ is the imported inputs for firm i, m_{ijct} is the total material inputs for firm i in country c sector j at time t. Note that the imported inputs may be influenced, as other things except the quality, by the transportation costs for example. It may therefore lower the demand for the imported inputs. However, comparing both measures of Eq. (6) and Eq. (7) would let us observe a range of magnitude for the forward spillovers on firm productivity. In doing so, an assumption that firm acquires from multinationals coming from country c the same as they acquire from country c.

To relax assumption A2, information on domestic firm's actual supplies to the down-

stream multinationals is required. In doing so, we take the data on "What proportion of your total sales is sold domestically" and "What proportion of your total domestic sales is to multinationals located in your country". These data are available in BEEPS waves 2002, 2003 and 2005, which are the perfect data for estimating backward linkage spillovers at firm-level[4]. We therefore calculate the backward linkages as

$$Backward_{ijct}^{firm} = \delta_{ijct}\alpha_{ijct}Sales_{ijct} \tag{8}$$

where

$$\alpha_{ijct} = \frac{SalestoDomesticMarket_{ijct}}{TotalSales_{ijct}}$$

and

$$\delta_{ijct} = \frac{DomesticSalestoMultinationals_{ijct}}{TotalDomesticSales_{ijct}}$$

α_{ijct} is the proportion of total domestic sales from firm i in country c sector j at time t to multinationals, and δ_{ijct} is the proportion of total sales to domestic market. $Sales_{ijct}$ is the total sales of firm i at sector j in time t. This is a firm-level measure that indicates the strength of the supply-customer (backward linkages) chain between downstream multinationals and upstream domestic firm. All above measures are less restrictive compared with the standard measures in the literature.

3.2 Econometric Approach

3.2.1 Production Function Estimation

Initially total factor productivity is constructed. The first step in the analysis requires the estimated parameters to eliminate firm-specific measure of productivity for each firm in the sample. As early studies generally estimate an augmented Cobb-Douglas production function by using standard OLS estimator, especially when data are pooled, this approach is followed (see, for instance, Javorcik, 2004; Gorodnichenko, Svejnar, & Terrell, 2010;

[4]Note that Gorodnichenko et al. (2014) only used the data of "What proportion of your total domestic sales are to multinationals located in your country" from the wave 2005, as they mentioned that the data were only available in that time. Therefore they were not able to construct a firm-level measure of backward linkages. However, after further exploring the dataset, we find that this data are also available in the waves 2002 and 2003. We therefore see this as an unique and novel measure on backward linkages.

Gorodnichenko et al., 2014). To mitigate potential biases, industry fixed, country fixed and year fixed effects are incorporated in the production estimation.

The first step of the estimation strategy is to regress firm's outputs on the capital stock, labour and material inputs. The empirical estimation is based upon a Cobb-Douglas production function that is shown as follow

$$lnY_{ijct} = \beta_0 + \beta_L lnL_{ijct} + \beta_K lnK_{ijct} + \beta_M lnM_{ijct} + s_j + \tau_t + z_c + \varepsilon_{ijct} \tag{9}$$

where L_{ijct}, K_{ijct} and M_{ijct} are the logarithm of employment, capital and materials that used by firm i in country c sector j at time t, and Y_{ijct} is the logarithm of firm's total sales. Note that there is a potential simultaneity bias in input choices in the production estimation and this can be addressed by employing the semiparametric estimation procedure suggested by Olley and Pakes (1996) and Levinsohn and Petrin (2003). Since, however, both approaches require a long period panel data, the time dimension of the data is insufficient to implement this approach. Gorodnichenko et al. (2014), on the other hand, suggest that by adding fixed-effects for country and industry to the specification this can control for the potential selection and endogeneity of inputs. The s_j industry fixed effects and z_c country fixed effects are therefore included in the model. In addition, following Newman et al. (2015), including a full set of time dummies can mitigate for heterogeneity over time in the production function and productivity. Hence, the time fixed-effects τ_t is also included in the empirical estimation. Once consistent estimators for β_L, β_K and β_M are estimated, productivity (the residual $\hat{\varepsilon_{ijct}}$ can be estimated using Eq. (10)

$$\hat{\varepsilon}_{ijct} = lnY_{ijct} - \hat{\beta}_L lnL_{ijct} - \hat{\beta}_K lnK_{ijct} - \hat{\beta}_M lnM_{ijct} \tag{10}$$

from Eq. (10), the derived productivity residual will be regressed on the FDI spillovers and other covariates.

3.2.2 Second Step Pooled OLS Estimation

The benchmark regression for measuring spillovers on firm's performance, which is the second step of productivity estimation, with pooled OLS across economies, industries and firms is given as

$$\hat{\varepsilon}_{ijct} = \alpha_0 + \alpha_1 Horizontal_{jct} + Forward^{'}\beta + Backward^{'}\gamma + s_j + \tau_t + z_c + \omega_{ijct} \tag{11}$$

where $\hat{\varepsilon_{ijct}} = lnY_{ijct} - \hat{\beta_L} lnL_{ijct} - \hat{\beta_K} lnK_{ijct} - \hat{\beta_M} lnM_{ijct}$ denoted as the productivity residual, $Backward'$ refers to the measures constructed by using input-output matrixes from the 12 countries, and constructed by Eq. (3), and the logarithm of firm-level backward linkages constructed by Eq. (8); $Forward'$ refers to the one constructed by using input-output matrixes from 12 economies as in Eq. (2), and the others constructed by Eq. (6) and Eq. (7) (as $Forward_{jct}^{IO}$, $Forward_{ijct}^{proxy-buy}$ and $Forward_{ijct}^{proxy-imp}$ respectively). The s_j industry fixed effects, τ_t time fixed effects and z_c country fixed effects are included in.

3.2.3 Omitted Variable Biases

Assuming that the error term is uncorrelated with the explanatory variables would likely suffer from omitted variable biases. Three robustness checks are conducted with regards to omitted variable biases: (1) firm's motivation and technology acquisition; (2) the supply-backward effects and (3) the macro environment effects.

First, firm's motivation in whether they attempt to be with joint venture foreign ownership would probably bias the estimated spillover effects. It can be argued that for firm who attempts to be with foreign joint venture would try to have more contacts with multinationals via customer-supply chain and hence would perform better than other firms. We take the data on whether domestic firms agree a new joint venture with foreign partner or not and set up as a dummy variable. It may also be the case that the firm who uses more advanced technology would obtain more FDI spillovers. Not taking these factors into account may bias the estimated coefficients. We therefore employ data on whether domestic firms acquire new production technology or not in the last 36 months and again set up as a dummy variable. These factors are controlled for in the following equations

$$\begin{aligned}\hat{\varepsilon}_{ijct} = \alpha_0 + \alpha_1 Horizontal_{jct} & \\ & + \alpha_2 Backward_{ijct}^{firm} + Forward_{ijct}^{'}\beta \\ & + Forward_{ijct}^{Motivated} k \\ & + \alpha_3 Backward_{ijct}^{Motivated} + Forward_{ijct}^{Newtechnology}\lambda \\ & + \alpha_4 Backward_{ijct}^{Newtechnology} \\ & + s_j + \tau_t + z_c + \omega_{ijct}\end{aligned} \tag{12}$$

where

$$Forward_{ijct}^{Motivated} = Forward_{ijct}^{'} D_{agree} \tag{13}$$

$$Backward_{ijct}^{Motivated} = Backward_{ijct}^{firm} D_{agree} \tag{14}$$

$$Forward_{ijct}^{Newtechnology} = Forward_{ijct}^{'} D_{Newtecnologyh} \tag{15}$$

and

$$Backward_{ijct}^{Newtechnology} = Backward_{ijct}^{firm} D_{Newtechnology} \tag{16}$$

where $Forward_{ijct}^{'}$ refers to $Forward_{ijct}^{proxy-buy}$ and $Forward_{ijct}^{proxy-imp}$, D_{agree} is 1 if domestic firm agrees a new joint venture with foreign partner and 0 if disagrees and $D_{Newtechnology}$ is 1 if domestic firm acquired new technology and 0 if not.

Second, it can be argued that firms in both streams would benefit from upgrading industry. For example, domestic firms in downstream sectors can benefit from the upstream domestic firms who engage in supplying products to the downstream multinationals, as downstream multinationals may deliberately transfer technology to upstream suppliers and upstream suppliers may then supply these materials to the other downstream domestic firms. Markusen and Venables (1999) call this "supply-backward spillover". Blalock and Gertler (2008) find that the effect of buying inputs from the firm that previously supplied to multinationals is significantly negative on firm profits, while Jude (2016) confirms that the effect of domestic firms who share the same suppliers of foreign affiliates is negative and significant on firm productivity. Following Jude (2016), the variables are constructed

$$Backward_{ijct}^{supply-back} = \delta_{ijct}\alpha_{ijct} Forward_{ijct}^{'} \tag{17}$$

where δ_{ijct} and α_{ijct} are the proportion of outputs sold to the multinationals, $Forward_{ijct}^{'}$ refers to $Forward_{ijct}^{proxy-imp}$ and $Forward_{ijct}^{proxy-buy}$.

As above, these variables are added into the empirical specification to detect whether the spillover effects found previously are affected or not as follow

$$\begin{aligned} \hat{\varepsilon}_{ijct} = \alpha_0 + \alpha_1 Horizontal_{jct} + \alpha_2 Backward_{ijct}^{firm} + Forward_{ijct}^{'}\beta \\ + \alpha_5 Backward_{ijct}^{supply-back'} + s_j + \tau_t + z_c + \omega_{ijct} \end{aligned} \tag{18}$$

where $Forward_{ijct}^{'}$ and $Backward_{ijct}^{supply-back'}$ are defined as above.

Third, it could be argued that multinationals may be attracted by the political stability and protection. Such spillovers may not be existed due to the reasons. The BEEPS survey asks each firm to respond question on "What is the level of obstacle of the next items to the functioning of this establishment?", which provides information on how the firm obstruct from the issue of political instability, macroeconomic instability and corruption, by saying 0 for no obstacle, 1 for minor obstacle, 2 for moderate obstacle, 3 for major obstacle and 4 for very severe obstacle. As these data are collected at firm-level, it is possible to examine whether the previous results are potentially biased by these factors. To shed light on this, the model is extended by controlling for (a) firms that reported for major and severe obstacle in political instability and (b) firms that reported for major and severe obstacle in macroeconomic instability and (c) firms reported for major and severe obstacle in corruption issues. The model is modified as follows:

$$\begin{aligned}\hat{\varepsilon}_{ijct} = \alpha_0 + \alpha_1 Horizontal_{jct} + \alpha_2 Backward^{firm}_{ijct} + Forward'_{ijct}\beta + \alpha_6 Political_{ijct} \\ + \alpha_7 Macroeconomic_{ijct} + \alpha_8 Corruption_{ijct} + s_j + \tau_t + z_c + \omega_{ijct}\end{aligned} \tag{19}$$

where $Forward'_{ijct}$ refers to $Forward^{firm}_{ijct}$ and $Forward^{proxy-imp}_{ijct}$ respectively.

3.2.4 Correlated Random Effects Estimation

There is still a potential econometric concern, since we assumes that firm has no individual effects existed. The omission of unobserved individual effects may exist, which may potentially bias our estimates. Haskel et al. (2007) suggests that the firm who has more high-quality management or has better infrastructure in a given region may perform better than the other. Since these factors may be unknown to the econometrician but known to the firm, it would therefore lead to bias estimates. This issue can be addressed by employing firs differenced (or fixed-effect) model to remove any fixed plant-specific unobservable variation and the fixed regional and industrial effects.

However, this approach may lead to another econometric concern. First, first-differenced approach leads to aggravate measurement error in the regressors, unless a longer time differences are applied (Griliches & Hausman, 1986). Second, once whole cross-section is used up to estimate the fixed-effects there is inefficiency due to data loss. Third, since the estimator relies on within variation, the estimates are imprecisely estimated if variation is small. The effects of such variables can neither be estimated nor enter the regression if there is no within variation at all. Since the time-period applied in this study is very short, this approach is not followed. Finally, measurement error gets

worse under differencing/de-meaning, and the bias caused might outweigh the bias from using Random-effect model incorrectly.

Instead, the Correlated Random Effects (henceforth, CRE) model is applied to tackle the above concerns. First, CRE approach still allows the unobserved individual effects to be correlated with the other explanatory variables. Second, the CRE approach provides a simple and formal way of choosing between the Fixed-effect (henceforth, FE) and Random-effect (henceforth, RE) estimators. Although Hausman's test is informative for deciding whether FE is more appropriate than RE, i.e., whether the unobserved firm's individual effect is correlated with the error term, (Wooldridge, 2012, Ch14) suggests that CRE approach provides a more intuitive regression-based test and overcomes the drawback[5] of using Hausman's test. Third, in the FE (or First-differenced when time-period is two) the correlation between x_{ijct} and $\bar{x}_{ijc}$ can result in a higher variance for the estimated coefficients. The variance would be even higher when there is little variation in x_{ijct} across time t, in which case x_{ijct} and $\bar{x}_{ijc}$ tend to be highly correlated. In the limiting case where there is no variation across time for any firm i, it would be perfect collinearity and FE fails to provide estimates. On the other hand, RE estimator has no bearing on the variance and performs better than the FE estimator. Fourth, with an unbalanced panel due to attrition (presumably the firm that is missing in the wave 2005 would probably have gone out of business or have merged with other companies, for example), FE is biased and inconsistent, even though the Hausman's test provides a large Chi-squared test statistic rejecting RE in favour of FE. The CRE approach also provides a way to include time-constant explanatory variables, which is not possible in the FE estimator. Lastly, we should be aware that RE estimator is more suitable if data consist of large N but small T (Wooldridge, 2012 Ch14).

The idea of CRE approach is to allow the omitted firm's individual effects to be correlated with the average level of each explanatory variable x_{ijct} rather than assume that it is uncorrelated - which is the random effects approach, the firm's individual effects can be thus decomposed as follows:

$$a_i = \sigma + \gamma \bar{x}_{ijc} + r_i \tag{20}$$

where $r_i jct$ is uncorrelated with each x_{ijct} and $\bar{x}_{ijc}$ is the time averages variable ($\bar{x}_{ijc} = T^{-1} \sum_{t=1}^{T} x_{ijct}$). As $\bar{x}_{ijc}$ is a linear function of the x_{ijct}, the Cov($\bar{x}_{ijc}$, r_i)=0. It follows that a_i and $\bar{x}_{ijc}$ are correlated whenever $\gamma \neq 0$.

[5](Wooldridge, 2012, Ch14) suggests that any variable that varies by time or by 'individual' only should not be part of the test. However, as the test results provided by STATA, it always be the wrong one.

Now assume that Eq. (10) suffer from omission bias, and we would like to mitigate this bias by allowing firm's individual effects into the model

$$lnY_{ijct} = a_i + \beta_L lnL_{ijct} + \beta_K lnK_{ijct} + \beta_M lnM_{ijct} + s_j + \tau_t + z_c + \vartheta_{ijct} \tag{21}$$

substituting Eq. (20) into Eq. (21) will give the following equation

$$lnY_{ijct} = \sigma + \bar{x}^{'}\gamma + r_i + \beta_L lnL_{ijct} + \beta_K lnK_{ijct} + \beta_M lnM_{ijct} + s_j + \tau_t + z_c + \vartheta_{ijct} \tag{22}$$

where $\bar{x}^{'}$ refers to the time average variable of employment, capital and material uses.

It is clear to see that the assumption Cov(a_i,x_{ijct})=0 holds when a_i is replaced by r_i. Also, because ϑ_{ijct} is assumed to be uncorrelated with x_{ijct}, hence ϑ_{ijct} will be uncorrelated with $\bar{x}^{'}$. In addition, the correlation between x_{ijct} and a_i is now controlled by the $\bar{x}^{'}_{ijc}$, therefore r_i is uncorrelated with x_{ijct}. All the assumptions above are added to the model. The estimated parameters of employment, capital and materials will therefore be used to extract firm's estimated productivity (residual).

The same CRE approach on the second step of productivity estimation is applied as follow

$$\begin{aligned} \bar{\vartheta}_{ijct} = c + \bar{x}^{'}\delta + \varphi_i + b_1 Horizontal_{jct} & \\ + b_2 Forward^{'}_{ijct} + b_3 Backward_{ijct} & \\ + s_j + \tau_t + z_c + \rho_{ijct} & \end{aligned} \tag{23}$$

where $\bar{\vartheta}_{ijct}$ is the estimated productivity residual, and all other right-hand side variables are defined above. Wooldridge (2012) notes that if the panel data set is unbalanced, then the average of variables such as time dummies can change across firms - it will depend on how many periods we have for cross-sectional firms. In such cases, the time averages of any variable that changes over time must be included. Therefore, all time average variables are included in the model. To control for omitted variable biases, Eq. (11), Eq. (12), Eq. (18) and Eq. (19) will also be re-estimated by CRE approach as follows

$$\begin{aligned} \bar{\vartheta}_{ijct} = c + \bar{x}^{'}\delta + \varphi_i + b_1 Horizontal_{jct} + b_2 Backward^{firm}_{ijct} + Forward^{'}_{ijct}\beta & \\ + Forward^{Motivated'}_{ijct} k + b_4 Backward^{Motivated}_{ijct} + \tau_t + z_c + \rho_{ijct} & \end{aligned} \tag{24}$$

$$\bar{\vartheta}_{ijct} = c + \bar{x}^{'}\delta + \varphi_i + b_1 Horizontal_{jct} + b_2 Backward^{firm}_{ijct} + Forward^{'}_{ijct}\beta + Forward^{Technology'}_{ijct}\lambda + b_5 Backward^{Technology}_{ijct} + \tau_t + z_c + \rho_{ijct} \tag{25}$$

$$\bar{\vartheta}_{ijct} = c + \bar{x}^{'}\delta + \varphi_i + b_1 Horizontal_{jct} + b_2 Backward^{firm}_{ijct} + Forward^{'}\beta + b_6 Backward^{supply-back}_{ijct} + \tau_t + z_c + varepsilon_{ijct} \tag{26}$$

$$\bar{\vartheta}_{ijct} = c + \bar{x}^{'}\delta + \varphi_i + b_1 Horizontal_{jct} + b_2 Backward^{firm}_{ijct} + Forward^{'}_{ijct}\beta + b_7 Political - instability_{ijct} + b_8 Macroeconomicinstability_{ijct} + b_9 Corruption_{ijct} + \tau_t + z_c + \varepsilon_{ijct} \tag{27}$$

3.2.5 Instrumental Variable Approach

Endogeneity is another econometric concern for the FDI spillovers. For illustration, consider the problem of unobserved factor that potentially impact on firm's output supply. The benchmark estimation now cannot provide unbiased estimates because

$$\hat{\varepsilon}_{ijct} = w^{'}\beta + e_{ijct} \tag{28}$$

$$E(\hat{\varepsilon}_{ijct}|X^{FDISpillovers}) = \beta E(w^{'}|X^{FDISpillovers}) + E(e_{ijct}|X^{FDISpillovers}) \neq 0 \tag{29}$$

where $E(e_{ijct}|X^{FDISpillovers}) = 0$ and $w^{'}$ refers to the unobserved factors that potentially determine firm's supply and source status and may indirectly distort FDI spillovers on firm's productivity. The above equations imply that the condition $Cov(X^{FDISpillovers}, \varepsilon) \neq$, which will provide biased and inconsistent estimates. To obtain consistent estimators of each estimate, instruments are required that can help to mitigate the potential correlation between the spillover variables and the error term.

However, it is somehow difficult to find suitable instruments that can tackle above issue. Fortunately, BEEPS data provide number of potential instrument. Hence in order for the instruments to be valid for spillover linkages, the following assumptions must be satisfied

(i) Exogenous condition: z is uncorrelated with

$hat\varepsilon$, that is

$$Cov(z, \hat{\varepsilon}) = 0 \tag{30}$$

(ii) Correlation condition: z is correlated with FDI spillovers, that is

$$Cov(z, X^{'}_{FDISpillovers}) \neq 0 \tag{31}$$

(iii) Exclusion condition: z does not belong in the benchmark equations.

For the exogenous condition, the common sense and economic theory should be used to decide whether the assumption $Cov(z, \hat{\varepsilon}) = 0$ is valid. For correlation condition, we can test whether $Cov(z, X^{'}_{FDISpillovers}) \neq 0$ in the first-stage regression

$$X^{'}_{FDISpillovers} = d_0 + d_1 z_{ijct} + e_{ijct} \tag{32}$$

Assume that all three conditions are satisfied, then the complete model is now rewritten as the reduced form and can be estimated on the second-stage

$$\hat{\varepsilon}_{ijct} = (\alpha_0 + \beta d_0) + \alpha_1 Horizontal_{jct} + Forward^{'}_{ijct}\beta + Z^{'}d\beta + s_j + \tau_t + z_c + (\omega_{ijct} + e_{ijct}) \tag{33}$$

where $Z^{'}$ is a set of instruments including collateral, overdue payments and unofficial payment for backward linkages (the supply status).

3.2.6 Replication - GST Estimation

In order to demonstrate that the our proposed measures would identify the spillovers better than the standard measures, we replicate the estimations of Gorodnichenko et al. (2014). Since we all use BEEPS firm-level survey dataset, their estimations are chosen to be replicated. In doing so, two empirical models are replicated. The first specification follows Gorodnichenko et al. (2014) with the first-differenced estimation for only 12

economies in 2002 and 2005 (denoted GST1)[6]

$$\begin{aligned}\Delta lnY_{ij} = \beta_H \Delta Horizontal_j + \beta_F \Delta Forward_j + \beta_B \Delta Backward_j \\ + X_{ij}\gamma + \beta_L \Delta lnL_i + \beta_K \Delta lnK_i + \beta_M \Delta lnM_i + z_c + \varepsilon_{ij}\end{aligned} \tag{34}$$

where X_{ij} is a set of country and industry dummy variables, $Horizontal_j$ refers to the FDI horizontal spillovers, $Forward_j$ and $Backward_j$ are the forward and backward linkages, as the average share of domestic firms' inputs purchased and sales supplied to foreign firms, constructed by using input-output matrixes at sector level[7].Following the authors, the industry dummies are suggested to be interacted with each input variable in order to allow for industry-specific production functions.

The second replication, which attempts to address potential selection issue of FDI and the potential endogeneity of inputs, follows Gorodnichenko et al. (2014) with the Solow residual and all fixed-effects including time dummy variable as below (denoted GST2)

$$\Delta Solow_{ij} = \beta_H \Delta Horizontal_j + \beta_F \Delta Forward_j + \beta_B \Delta Backward_j + X_{ij}\gamma + \varepsilon_{ij} \tag{35}$$

where $Solow_{ij} = lnY_{ij} - lnL_i - lnK_i - lnM_i$ and the industry and country fixed-effects are allowed in the Solow production function. For the comparison purpose, the replicated estimations are therefore regressed on both standard measures (as conducted by Javorcik (2004)) and the weighted measures (as conducted by Gorodnichenko et al. (2014)).

4 Data

The data for the empirical investigation are taken from the European Bank for Reconstruction and Development (EBRD) conjoined with Word Bank Business Environment and Enterprise Performance Survey (BEEPS). The BEEPS, as a raw firm-level dataset,

[6]The authors estimate FDI spillovers on firm productivity for only 17 economies in the year 2002 and 2005, including Albania, Bulgaria; Croatia, Czech Rep., Estonia, Georgia, Hungary, Kazakhstan, Latvia, Lithuania, Poland, Romania, Russia, Serbia, Slovakia, Slovenia and Ukraine. Unfortunately, the estimation does not include these six countries including Albania, Croatia, Georgia, Kazakhstan, Serbia, and Ukraine. This is due to the data limitation in OECD database. However, we were unsuccessful for the following countries: Albania, Croatia, Georgia, Kazakhstan, Serbia, and the Ukraine - where we were unable to find the required information. On the other hand, we include in the replication, as Turkey contributes to the number of observations in the sample size.

[7]Gorodnichenko et al. (2014) define forward and backward linkages as $Forward_j = \sum_j \frac{(Horizontal_d \delta_{dj}^{IO})}{(\sum_j \delta_{dj}^{IO})}$ and $Backward_j = \sum_j \frac{(Horizontal_j \delta_{jd}^{IO})}{(\sum_j) \delta_{jd}^{IO})}$, weighted by the sales of industry j sold to and purchased from industry d.

was prepared by the World Bank's Enterprise Survey team as a courtesy to the users. It covers BEEPS rounds from 2002 onwards. This survey dataset covers firms in both services and manufacturing sectors and relies on the same sampling frames. Identical questionnaires are used in all countries, which makes the empirical evidence more reliable and comparative compared to the existing literature. The BEEPS dataset approaches large number of observation with a core 41-page questionnaire module via standard interview supported by the EBRD and the World Bank, and 46- and 44-page questionnaire modules for manufacturing and services sector respectively.

The analysis primarily matches the BEEPS 2002, 2003 and 2005 surveys, as a pooled data, because it contains data with information on firm supply (how much they sold to multinationals) and joint ownership activities. This produces a unique and rich database that allows us to explore the vertical linkages between the domestic and multinational firms. The total surveyed firms across 32 economies and 8 sectors through 2002, 2003 and 2005 are detailed in Tables 2 and 3 and 4. We carry out the largest number of observations compared with the study of Gorodnichenko et al. (2014).

Since this is a special designed survey, trained interviewers have conducted face-to-face interviews and all participants are anonymous. The individual perception bias can be disregard, as Fries, Lysenko and Polenac (2003) find no significant perception biases across the countries in the sample. Godart and Görg (2013) also suggest that the perception bias should be of less concern, as BEEPS survey follows a similar methodology. In this regard, although some of survey questions change slightly, it is important to note that the results of the analysis will not be affected by the bias.

To calculate firm's productivity, the survey provides crucial information on the share of firm's sales, the raw material uses, employment and capital stock. In more specific, the survey asks each firm "How many permanent, full- time employees does your firm have?" and "In fiscal year what were the total annual sales of this establishment?" and "What was the net value of assets after depreciation of the machinery and equipment (including vehicles), Land and buildings at the end of fiscal" and "How much was the raw materials and bought in components/services". The answers to these questions are used to calculate the measure of firm productivity. Note that there is a potential simultaneity bias in input choices in the production estimation (see, for more detail, Olley & Pakes, 1996; Levinsohn & Petrin, 2003). However, due to the data limitation no sufficient data to implement above approaches, because both approaches require a long period panel data. Nevertheless, this potential bias can be mitigated by our proposed measures on both vertical linkages as well as a rich set of instrumental variables.

To calculate standard vertical spillover measures, data from input-output tables are provided by the Organization for Economic Co-operation and Development (OECD) Structural Analysis (STAN). We employ OECD STAN I-O 2012 latest Matrix for the analysis. As they are only available for 7 OECD member countries (they are, Czech Republic, Estonia, Hungary, Poland, Slovakia, Slovenia and Turkey) and 5 non-OECD countries (they are, Bulgaria, Latvia, Lithuania, Romania, Russia), standard measures are constructed for these 12 countries only due to this data limitation. Note that the our firm-level data are based in early 2000s, so all matrixes from the early 2000s across these countries are used except Latvia and Lithuania[8]. Note that the coefficients taken from early 2000s period IO matrixes are only for within-economy intermediate consumption of goods. They exclude imports. The sector classification specified is given solely by the BEEPS dataset (see Table 4 for more information).

For the main proposed measures on backward linkages, information on firm sales to multinationals is used. This information is based on the questions "What proportion of your total domestic sales" and "What proportion of your total domestic sales is to multinationals located in your country (not including your parent company, if applicable)". We therefore construct our firm-level backward linkages based on the two questions.

The information on outputs sold to large domestic firms is used. We take the data on "What proportion of your total domestic sales is to the large domestic firms" and "What proportions of total sales are to the sectors Mining and quarrying, Construction, Manufacturing, Transport storage and communication, Wholesale, retail, repairs, Real estate, renting and business services, Hotels and restaurants, and others to construct our proposed firm-level measure on forward linkages.

We also take the information on firm domestic sources and imported inputs. The question in "What proportion of your establishment's material inputs and supplies are purchased from domestic sources" and "What proportion of your establishment's material inputs and supplies are purchased from imported directly" are therefore applied to construct our proposed measure on $Forward_{ijct}^{proxy-buy}$ and $Forward_{ijct}^{proxy-imp}$. Table 2 provides an overview for the information on firm sourcing and purchasing behaviour by country origin. Table 3 provides the summary statistics for each explanatory variable. Table 4 provide information for the sectors specified in our data.

From Tables 5 and 6, it shows that firms who supplied outputs to multinationals or purchased from multinationals have higher performance in terms of capital stock, total

[8]No data for early 2000s period are available for these two countries. We therefore use data from the mid-2000s instead.

sales, material uses and number of employees compared with firms who did not supply to or purchased from multinationals. In terms of the firms who supplied to multinationals, they were about 27% and 17% higher in the capital stock than the firms who did not supply to multinationals in 2002 and 2005, while they were only 4% higher in 2003. The number of employees can be found even larger for the firms supplied to multinationals compared with the firms who did not, by about 84% and 75% in 2002 and 2005. Overall, the average firms that supplied to multinationals have produced 18% to 75% more outputs than the firms who did not supply to multinationals. A very similar pattern can also be found in Table 6.

In short, it seems that in average the firms who have the contact with multinationals across countries are more productivity than others, although, of course, this simple comparison does not allow any conclusions about the causal effect of being the suppliers or customers of multinationals. We therefore need the econometric investigation.

5 Results

5.1 GST Replication

The objective of this subsection is to compare the results obtained by the newly proposed measures on vertical FDI spillovers and the results obtained by the standard measures. The investigation of how these measures may perform differently in term of capturing productivity spillovers is crucial. The estimates of standard measures on FDI spillovers are reported in Table 7, while the alternative measures are reposted in Table 8. The number of observations is approximately 3,500 to 4,100 for the 12 economies due to the data limitation on input-output tables. To be consistent with GST estimation, the replication only regress firms surveyed in 2002 and 2005[9].

With the measures of Gorodnichenko et al. (2014) on backward and forward linkages, the results provided in Table 7 show no significant effects of FDI spillovers on firms productivity. In Columns (1) to (4), the signs of backward linkages are unclear. For example, backward linkage is confirmed as positive but statistically insignificant when it is measured at level, while it is confirmed as insignificantly negative when the weighted measures are applied. Both types are insignificant and the estimated coefficients even vary substantially across specifications, from 2.132 in column (1) to -10.88 in column (4). The same pattern is found on the measure of forward linkages, in which the estimated

[9]The authors only apply BEEPS waves 2002 and 2005. See Gorodnichenko et al. (2014) for more information

coefficients vary from -1.462 in column (1) to -10.14 in column (3) and 9.607 in column (4).

When GST2 estimation is employed[10], both measures on FDI spillovers perform badly with insignificant effects throughout. It reveals the fact that both standard IO and GST measures on vertical linkages do not capture the spillovers between multinationals and domestic firms based upon the 12 emerging economies. Note that the results presented in Table 7 may differ to the study of Gorodnichenko et al. (2014) due to the unavailability of input-output data for Albania, Croatia, Georgia, Kazakhstan, Serbia, and Ukraine are not available. In addition, the country Turkey, which is not included in Gorodnichenko et al. (2014), is included in our analysis. Although the full sample applied in Gorodnichenko et al. (2014) is not entirely same as us, based upon the same 11 economies and Turkey the standard measures do not provide evidence for firm productivity spillovers in our data.

On the other hand, by relaxing A1[11] and A2[12], the results show that using firm-level measure on backward and forward linkages produces more reliable and stable estimates. As can be seen in Table 8, backward linkages are confirmed as positive and statistically significant on firm productivity at 10% and 5% significance levels in GST1 and GST2 estimations. This finding is analogous to the findings in Javorcik (2004). On the other hand, forward linkage are confirmed as positive and statistically significant in column (3) of Table 8. Comparing the results in Tables 7 and 8, it suggests that while the standard measures do not capture the linkage spillovers from multinationals, using our proposed measure on backward and forward linkages do help to better identify the vertical spillovers on productivity from multinational to domestic firms.

5.2 Baseline Estimation

How well do the alternative measures work for estimating vertical spillovers on firm's productivity with the full dataset across 32 emerging economies compare with the standard measures? To answer this question, two econometric issues need to be concerned. The first is the endogeneity of firm's inputs choice, while the second is the issue of time-invariant variables[13]. To tackle the former, the two-step production estimation procedure

[10]GST2 takes the potential endogeneity of inputs into account

[11]The assumption is that the outputs supplied from multinationals upstream to the domestic firms downstream is the same as it supplied by local firms upstream to local firms downstream

[12]The assumption is that domestic firms upstream supply outputs to multinationals downstream the same as multinationals downstream source inputs from local firms upstream

[13]The following reasons should be noted. First, FE (first-differenced if time period is two) approach leads to aggregated measurement error in the regressors(Griliches & Hausman, 1986). Second, once whole cross-section is used up to estimate the FE there is inefficiency, because it filters out all the effects

is employed. To overcome the latter, we apply the CRE approach in the second-step of production estimation. However, as the literature (e.g., Gorodnichenko et al., 2014; Newman et al., 2015) usually apply the FE estimation, the results obtained by FE and pooled OLS approaches are also provided in the Tables.

Table 9 presents the results of the first step production estimation provided by the pooled OLS, FE and CRE estimators. The results confirm the significance of capital, materials and employment on firm's productivity. They are all positive and statistically significant at 1% significance level. The results between the three estimators are not much different, which imply that firm's time-invariant heteroskedastic does not affect firm's performance. With the consistent estimated parameters, the next step is to extract the predicted value from the total factor productivity estimation as the dependent variable in our baseline regression models. This mitigates potential inputs biases and helps us to get consistent estimates.

The results of estimation Eq. (11) are presented in Tables 10, 11 and 12 with different estimators throughout. Note that the standard measures on backward and forward linkages are constructed only for 12 economies due to the data limitation on input-output tables. Column (1) in each Table provides results when assumptions A1 and A2 are held simultaneously. The estimated coefficients of standard forward and backward linkages are confirmed as statistically insignificant, meaning that no spillover effects on firm productivity are captured in our data. This might due to the measurement error when combining firms' sourcing and supplying information with IO tables.

However, when assumption A2 is relaxed while holding assumption A1, we find that the results in column (2) in Tables 10, 11 and 12 suggest statistically significant spillovers of backward linkage on firm productivity. The standard forward measure is confirmed as statistically insignificant, although positive. The estimated coefficients also vary through columns (1) and (2). This would therefore suggest that holding the assumption that downstream domestic firms source inputs from upstream multinationals the same as local firms downstream source inputs from local firms upstream leads to bias on measuring spillovers from forward linkages.

Columns (3) and (4) of Tables 10, 11 and 12 provide results when assumption A1 is relaxed only. In doing so, the standard measure of backward linkages is employed again, but the two proposed measures of forward linkages are employed to replace the standard IO. Due to the data limitation, these estimations are still restricted for the 12 economies

of unchanging. Third, since FE relies on within variation, the estimates are imprecisely estimated if variation is small.

only. When running the regressions, first the results of columns (3) and (4) in Tables 10 and 12 show that the proposed measures successfully capture the positive spillovers on firm productivity through forward linkages at 1% significance level. The estimated coefficients are 0.017 for $Forward^{proxy-imp}$ and 0.011 for $Forward^{proxy-buy}$, which suggest that the true effect from forward linkages would somewhere between this range. Although the result provided by Fixed-effect estimator in columns (3) and (4) of Table 11 shows no significant effect from forward linkage, we doubt that it is due to the lack of within-variation.

Comparing results in columns (1), (2), (3) and (4) in each Table thus suggests that the variation in firms sourcing and supplying behaviour plays a determinant role and neither holding assumption A1 nor A2 can capture the effect of vertical spillovers. By either relaxing assumption A1 or A2 does make some difference for identifying the effect coming form vertical linkages.

Next, to see how biased the results would be by holding assumption A2 and A1, the model is now estimated by using the measures on backward and the forward linkages constructed in Eq. (6), Eq. (7) and Eq. (8), where they are all under the relaxation of A1 and A2. The results are provided in columns (5) and (6) through Tables 10 to 12. By relaxing assumptions A1 and A2, we find that both linkages are confirmed as statistically positive and significant with pooled OLS and CRE estimations, while forward linkages are of statistically insignificant with FE estimator. Comparing with the estimated coefficients within three estimators, the measures on backward spillovers rarely change in magnitude, although the standard errors provided by FE estimator are remarkably larger than the others provided by OLS and CRE estimators.

In general, both proposed measures are identified as positive and significant at 1% significance level. This finding remains when we extend sample size from 12 economies to 32 economies. We find that while the estimated coefficients of backward linkages are always significant with estimated coefficients between 0.026 and 0.031 by CRE and 0.033 and 0.047 by FE estimator, the significance of forward linkages seems not always to be the case. However, as suggested by Wooldridge (2012), the weak within-variation would result in less efficient estimates in FE estimation. We therefore focus more on discussing results provided by pooled OLS and CRE for the rest analysis.

Above results deserve further discussion. First, by holding A1 but relaxing A2 at firm-level, both measures produce positive coefficients with respect to firm productivity, but only the measure of backward linkages captures the productivity spillovers. Second, by relaxing A1 but holding A2 for the 12 economies, only the measure of forward link-

ages captures the productivity spillovers, while standard measure of backward linkages does not provide any evidences of productivity spillovers. Third, by relaxing A1 and A2 simultaneously, the spillovers are identified for not only the 12 countries, but also for all 32 economies. The results show that both forward and backward linkages are indeed statistically positive and significantly associated with domestic firm performance. These findings, therefore, highlight the importance of relaxing the assumptions and suggest the existence of positively vertical spillovers in these 32 economies.

5.3 Extension and Robustness Checks

5.3.1 Will Firm's Motivation and New Technology Acquisition Affect Spillovers?

Before we move on to the assumption of exogeneity of the supplier status, we consider the potential variations through firm's motivation as well as technology acquisition. The positive spillovers would not hold if a firm is of high willingness to have a joint foreign ownership. The firm who is more willing to have a joint foreign ownership is expected to be more productivity due to firm's self-selection. Thus, the results obtained so far may partially reflect to the fact that the stronger the motivation in having foreign ownership, the higher the productivity. One way of alleviating this issue is to control for firm's motivation and technology acquisition.

The results are provided in Tables 13 to 14. First, we re-estimated Eq. (11) by including firm's motivation into the model. We find that the results remain. From columns (1) to (2) of Tables 13 and 14, the results suggest that firm's motivation does not necessary need to be concerned when we proxy the inputs of domestic firm sourced from multinationals by using firm's domestic sources. On the other hand, the estimated coefficients of backward and the proxy of forward linkages by using domestic firm's imported inputs are indeed affected slightly by the two omitted factors. It may suggest that domestic firm who tends to have a joint foreign ownership would benefit more from being the supplier of multinationals but would benefit less from being the buyer of multinationals. Nevertheless, this finding is not held when we swap the measure of forward linkages.

In columns (5) and (6) of Tables 13 and 14, we include both motivation and technology acquisition simultaneously into the specifications. In doing so, we find that our measure on backward linkages still enters significantly at 1% significance level with estimated coefficients 0.032 and 0.024 throughout. While we still find that the proxy of forward linkages by imported inputs remains its statistic significance at 1% significance level, we

do not find evidence of statistic significance from the measure of forward linkages proxyed by firm's domestic sources.

The results suggest that it does not generate spillovers from either supplying outputs to multinationals or purchasing inputs from multinationals through firm's motivation and technology acquisition. This is an important finding, as previous studies, e.g., Gorodnichenko et al. (2014) and Godart and Görg (2013), only confirm that supplying to multinational is not statistically related to higher gains in productivity. Note that since the estimated coefficients on backward and forward linkages are not affected by much, it might imply that the two variables might not be important in identifying FDI spillovers, i.e., neither the estimated coefficients of firm's motivation nor the new technology acquisition enter the specifications at any significance levels.

5.3.2 Supply-Back Bias?

We are now considering the supply-back effects from both linkages. It can be argued that domestic firms would either supply multinationals by using the inputs purchased from multinationals, or purchase the inputs of multinationals that were previously produced by the domestic firms. We therefore extend our model as Eq. (18).

The results are provided in Table 15. The results show that both forward and backward linkages remain as positive and statistically significant at 1% significance level through all specifications. The results strongly confirm the robustness of previous findings. With regard to the effect of supply-back, we find statistically significant and negative effect of supplying materials back to multinationals or of purchasing materials back from multinationals. It reveals the difficulties in benefiting from the second-order vertical linkages. We believe this is because that multinationals usually stand at a high level of technology and thus would often impose high quality standards to their suppliers or customers (Jude, 2016). Although we find that the supply-back linkages indeed generate some spillovers to the domestic firms, the estimated coefficients of the three proposed measures do not vary with the specifications. This, hence, provides further support for the vertical spillover effects.

5.3.3 Institutional Environments Bias?

Another factor that may affect spillovers is the institutional environment. It could be argued that multinationals may be attracted by political stability and protection. The results are provided in Table 16. The estimated coefficients on both backward and forward linkages are generally unchanged, they are all positive and significant at 5% and

1% significance levels. The institutional variables are generally confirmed, except the political instability. The results are fairly similar to those reported in the previous tables. If, however, the findings differed, then it would suggest that institutional environments do matter for having FDI spillovers throughout, and the proposed measures on forward and backward linkages would therefore not properly capture the spillovers on firm's performance. In contract, including the macro stabilities only affects the effect of horizontal spillovers. The the estimated coefficients differ dramatically, although the measure of horizontal is never confirmed as statistically significant.

Based on above estimates, the two proxies of forward and backward linkages perform well in capturing the spillover effects on firm productivity. Recall that by using standard measures on both vertical linkages, there is no evidence found for the spillovers on firm productivity. In contrast, relaxing both assumptions A1 and A2 while controlling for the potential variations show positive and statistically significant spillovers on firm productivity.

5.4 Endogeneity of Supplier Status

So far the results show that by taking potential biases into account our proposed measures indeed provide evidence of productivity spillovers through backward and forward linkages. However, these estimations may not be able to detect the endogeneity in the supplier status if more productive firms self-select to become suppliers of multinationals[14]. Therefore, we now use an alternative approach - the instrumental variable - for the proposed measure of backward linkages. Our estimation strategy is based on the detail firm-level information. As BEEPS data provide number of potential instruments, three instruments for backward linkage spillovers are considered:

Instrument 1: firm's cash flow might reflect to some exogenous shocks that may potentially influence the availability of such spillovers from multinationals to domestic firms. For example, a firm would delay payments to their upstream supplier if an unexpected loss in firm's incoming cash flow occurs (Gorodnichenko & Schnitzer, 2013). As multinationals in emerging economies may have more bargaining power and be internationally reliable debtor, domestic suppliers may be required to deal with their customers' overdue payment once an exogenous shock that affects multinationals' cash flow occurs. Resolving overdue payment would therefore be an indicator implying the correlation between domestic suppliers and multinational customers. It therefore suggests the relevance with

[14]We consider this issue based upon the suggestion of Barrios et al. (2011) and Gorodnichenko and Schnitzer (2013)

backward linkages but no direct relevance with productivity gains. As BEEPS collects information on the overdue payments made by each firm, this variable is employed as the first instrumental variable. However, as the questions differ through the survey waves, we only take the following question as our instrument:
"In the last two years, did this establishment have a dispute with clients over payments owed to it, in which the establishment had to engage a third party such as arbiters, collecting agency or judicial system?"
A dummy *Overdue* is set equal to 1 if a firm has overdue payment to suppliers and 0 otherwise.
Instrument 2: The second rational instrument is the total sales lost due to delivery delays, theft, breakage or spoilage. The loss of products would result a significant decrease in the number of products sold to the downstream multinationals, and hence would make the upstream domestic firm benefit less from the backward spillovers. This therefore satisfies the relevant condition. The BEEPS provides following information:
"what percent of the consignment value of products this establishment shipped to supply domestic markets was lost while in transit because of breakage or spoilage?" for the wave 2003 and 2005, and
"what percent of total sales was lost due to delivery delay from material input suppliers?" for the wave 2002
we combine these information and construct a variable *Lost* as the second instrument. As all lost products are expected to be exogenous and no unobserved factor would cause *Lost*, it implies the stratification of exogenous condition.
Instrument 3: The final instrument considered is unofficial payments. Unofficial payments in emerging economies can be thought as an important indicator that reveals the efficiency of investment market. An unofficial payment would be made if a firm is required by their customers. It might reflects the obstacle of operating an enterprise in the host-country. However, it would not influence a firm's productivity directly, as production efficiency should not be correlated with the unofficial payments. In addition, being required to make the unofficial payment is entirely exogenous, as it is not dependent on any other conditions. An unofficial payment is usually required by chance, and not easy to be observed. Fortunately, BEEPS asks each firm the following question:
"In reference to that application for an operating license, was an informal gift or payment expected or requested?"
We therefore take this unique opportunity to explore the idea of using unofficial payment as an instruments for our proposed measure of backward spillovers. The instrument is set

$InformalPayment$ equal to 1 if the firm were required to make an informal payment for an operating license and 0 otherwise.

To see how these instruments work, two different IV estimations are set up. First we employ instruments 1, 2 and 3 with the measure on $Forward_{ijct}^{proxy-imp}$; then we re-estimate our specifications with measure on $Forward_{ijct}^{proxy-buy}$. Panel A of Table 17 reports results from the first stage regression for the excluded instruments and the diagnostic tests[15].

All instruments enter the model with the expected signs and at least one of the instruments is confirmed as statistically significant at 1% significance level throughout the specifications. The F-statistics for the first stage regressions show that all instruments are jointly relevant, indicating no weak instruments in the model. The under-identification test also shows that the instruments are not weak with probability 0.000 throughout, while the over-identification (Hansen J) shows that the model is just identified with reasonable J-statistics (not being able to reject the null that the model is identified at 5% significance level).

Hence, we are confident with the instruments to mitigate the endogenous supplier status. Now considering the results from the second stage in Panel B of Table 17. First, the results show that the measure of backward linkages still enters the model significantly at 1% significance level. Based on this finding we can conclude that the positive effect of backward linkages is robust in any specifications. There is also evidence of a positive forward linkages on firm productivity, as we find that the estimated coefficients in column (2) is statistically positive and significant at 1% significance level. All the findings confirm the robustness of the proposed measures on capturing vertical spillovers on firm's productivity.

To see how sensitive above results are to the two-step production estimation, as suggested by Barrios et al. (2011), we re-estimate all specifications with an augmented production function by the FDI-linkage variables. The results are provide in columns (3) and (4) of Table 17. We find that these estimations still confirm the positive effect of backward linkages on firm productivity at 1% significance level throughout. However, only the measure of forward linkages by using domestic sources capture the spillover effects.

[15]The results are provided by using command "ivreg2" with "first" and "robust" option. The results obtained by using command "xtivreg" with "re" option are not provided, as some diagnostic tests, e.g., the F-statistic and Underidentification test, are not available after running "xtivreg". Nonetheless, both options provide similar results, and also the Hansen J overidentification tests from both options are almost identical. For more information about "iverg2", see Baum (2007)

6 Conclusion

Using a unique survey data for 32 Eastern Europe and Central Asia countries, we analysed the effect of FDI vertical spillovers from multinationals to domestic firms. We specifically addressed those assumptions that intensively used in the previous studies to measure the vertical linkages, including assumption A1 - domestic firms downstream source inputs from multinational upstream the same proportion as local firms downstream source from local firms upstream - and A2 - domestic firms upstream supply outputs to multinationals downstream the same as multinationals source inputs from local firms upstream. These assumptions were empirically relaxed by our proposed measures. We compared the estimated results from both standard and proposed measures.

We contributes to the literature by disentangling the puzzle of measures on FDI vertical spillovers. Javorcik (2004) highlights the positive spillovers from FDI on domestic firm's productivity. To show a clear picture of FDI spillovers coming from multinationals to domestic firms across industries between upstream and downstream sectors, she incorporates "host-country" sector-level input-output matrixes. Barrios et al. (2011) then argue that the measures used previously in the literature are restricted by unrealistic assumptions. To arrive at a clear aspect of the violation in those assumptions, they collect input-output matrixes from each "home-country" while employing multinational domestic sources to construct the measure on backward linkage spillovers. Arguably, using domestic firm's supply to multinationals while inferencing domestic firms input sources from multinationals, which does not rely on input-output matrixes, can identify the direction of vertical spillovers. This is the main novelty of this paper.

The empirical results reveal the fact that the standard measures that relied on input-output matrixes do not capture the vertical spillovers. To be specific, no clear evidence of such spillovers through backward and forward linkages for the 11 European and non-European countries can be captured by the standard measures. However, by using proposed measures, there is evidence of positive and statistically significant effects from both forward and backward linkages on firm productivity. Controlling for the endogeneity of supplier status, the results suggest that a one % increase in backward linkage raises the productivity of domestic firms by about 0.2 %, while a 1 % increase in forward linkages raises firm productivity by about 1.7 to 2.3 % throughout the model.

The results suggest that the differences among multinationals and domestic firms' sourcing and supplying behaviour in the host-country play a crucial role in hindering potential spillovers arising from both backward and forward linkages. It is difficult to model these differences by applying the assumptions seen in the literature. As can be

seen in our empirical results, it suggests that using firm's actual sourcing and supplying data help us to mitigate such biases caused by these differences. Although there is still a difficulty in the availability for such data in domestic firm's sourcing and supplying information, at least our measures mitigate this data restriction.

Based on the analysis, it may be appropriated to infer that our finding is a general result for the developing countries. It therefore suggests that while for those developing countries policy makers should keep focusing on the policies aimed at attracting multinationals, while encouraging domestic firms to have more contact with multinationals is needed.

However, as highlighted previously our analysis is based on a pooled data, our empirical estimates may still not be apart from the potential biases. While we relax assumptions applied in the literature, we also introduce four assumptions on the proposed measures of forward linkages. These limitations therefore call for more exercises to follow our proposed measures to investigate whether these potential variations might change the effects from the FDI spillovers.

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Tables

Table 1: Description of linkage spillovers.

Linkage indices	Description
Horizontal linkage	The potential productivity benefits for local firms from FDI within industry
Backward linkage	Downstream multinational firms source input materials from upstream domestic firms
Forward linkage	Upstream multinational firms supply outputs to the downstream domestic firms

Source: Author's classification based on FDI linkage spillovers literature (e.g., Javorcik, 2004; Javorcik & Spatareanu, 2008;Gorodnichenko et al., 2014; Newman et al., 2015).

Table 2: Sources and Supplies across Countries

Country	Code	Supply to multinationals		Purchase from multinationals			
	#	Mean	S.d	Mean	S.d	Mean	S.d
Albania	1	0.367	1.229	0.829	1.879	0.649	1.524
Armenia	2	0.805	0.164	0.202	0.486	0.780	0.736
Azerbaijan	3	0.710	1.768	0.141	0.276	0.348	0.333
Belarus	4	0.225	0.940	0.115	0.257	0.282	0.328
Bosnia	5	0.558	1.664	0.293	0.566	0.494	0.648
Bulgaria	6	0.575	1.763	0.098	0.228	0.333	0.320
Croatia	7	1.040	2.123	0.340	0.662	0.500	0.610
Czech Rep.	8	0.853	2.131	0.246	0.704	0.958	0.105
Estonia	9	1.035	2.290	0.188	0.371	0.442	0.479
FYROM	10	0.528	1.684	0.098	0.181	0.136	0.193
Georgia	11	0.370	1.332	0.097	0.201	0.249	0.254
Hungary	12	1.791	2.935	0.443	0.951	1.381	1.480
Kazakhstan	13	0.543	1.573	0.291	0.687	1.231	1.026
Kyrgyz	14	0.426	1.277	0.045	0.095	0.100	0.124
Latvia	15	0.793	1.908	0.106	0.276	0.241	0.328
Lithuania	16	0.630	1.716	0.221	0.511	0.528	0.648
Moldova	17	0.314	1.217	0.264	0.635	0.902	1.084
Montenegro and Serbia	18	0.857	2.141	0.409	1.037	0.926	1.103
Poland	19	0.886	2.125	0.299	1.059	1.994	1.799
Romania	20	0.673	1.876	1.056	3.159	4.830	5.819
Russia	21	0.380	1.424	0.093	0.287	0.583	0.483
Slovakia	23	1.068	2.301	0.192	0.336	0.321	0.344
Slovenia	24	0.659	1.853	0.185	0.332	0.307	0.410
Tajikistan	25	0.386	1.213	0.011	0.034	0.053	0.069
Ukraine	26	0.344	1.315	0.195	0.613	0.934	0.911
Uzbekistan	27	0.258	1.203	0.164	0.491	0.815	0.899
Yugoslavia	28	0.645	1.739	0.588	1.126	0.888	1.058
Turkey	29	0.535	1.733	0.054	0.171	0.507	0.450
Guatemala	30	2.714	5.505	0.442	0.807	1.101	1.040
Honduras	31	2.195	5.031	0.744	1.272	1.098	1.417
Nicaragua	32	2.468	5.137	0.567	1.431	2.122	2.140
Elsalvador	34	2.063	4.817	0.342	0.588	0.788	0.729

Source: Author's calculation.

Note: Montenegro and Serbia are not assigned in a same group in any other surveys in BEEPS dataset, but for the survey rounds in 2002, 2003 and 2005 they are assigned in one group. Ecuador is dropped off from the sample due to lot of missing values. The code 22 (Serbia) and 33 (Ecuador) are therefore not included.

Table 3: Summary Statistics

Variable	Definition	Obs.	Mean	SD	Max	Min
ρ	% owned by foreign	18,596	0.101	0.277	1	0
δ_{it}	% sales sold domestically	18,099	0.886	0.255	1	0
α_{it}	% sales to multinationals	18,004	0.040	0.161	1	0
c_{i1t}	% sales comes from sector 1	16,322	0.010	0.096	1	0
c_{i2t}	% sales comes from sector 2	16,322	0.103	0.291	1	0
c_{i3t}	% sales comes from sector 3	18,595	0.394	0.463	1	0
c_{i4t}	% sales comes from sector 4	16,322	0.070	0.247	1	0
c_{i5t}	% sales comes from sector 5	16,322	0.280	0.422	1	0
c_{i6t}	% sales comes from sector 6	18,595	0.085	0.266	1	0
c_{i7t}	% sales comes from sector 7	14,475	0.060	0.232	1	0
c_{i8t}	% sales comes from sector 8	18,099	0.055	0.213	1	0
μ_{ijt}	% of total inputs sourced domestically	17,975	0.695	0.380	1	0
$m_{ijt}^{imported}$	% imported inputs	17,969	0.163	0.313	1	0
$lnSales$	Total annual sales of the firm in log	13,703	6.975	3.606	22.829	0
$D^{Newtechnology}$	Dummy in new production technology acquisition	18,596	0.267	0.442	1	0
D^{agree}	Dummy in agreed with foreign joint venture	18,596	0.052	0.221	1	0
FDI spillovers						
$Horizontal$	Horizontal spillover; Eq.1	13,703	0.095	0.268	1	0
$Forward_{proxy}^{imp}$	Forward linkage using imported inputs; Eq.7	17,178	0.294	1.023	14.167	0
$Forward^{proxy-buy}$	Forward linkage using domestic sources; Eq.6	17,178	1.029	1.903	14.167	0
$Backward_{firm}$	Firm-level backward linkages in log; Eq.8	13,284	0.894	2.609	18.972	-2.813
$Forward_{IO}$	Input-output forward linkages; Eq.2	8,503	0.235	0.206	0.925	0
$Backward_{IO}$	Input-output backward linkages; Eq.3	8,503	0.224	0.183	0.9	0
$Forward_{GST}$	(Gorodnichenko et al., 2014) forward linkages at share; Eq.22	8,368	0.189	0.168	0.808	0
$Backward_{GST}$	(Gorodnichenko et al., 2014) backward linkages at share; Eq.22	8,368	0.181	0.144	0.7	0.003
Production function						
lnL	Number of full-time employees in log	18,545	3.119	1.660	9.206	0
lnM	Total annual costs of electricity in log	12,281	7.835	3.506	21.147	0
lnK	Capital stock in log	9,226	5.293	2.940	19.854	0

Source: Author's calculation.

Note: The values are expressed in U.S dollars. (Gorodnichenko et al., 2014) define forward and backward linkages as $Forward_j = \sum_j \frac{(Horizontal_d \delta_{dj}^{IO})}{(\sum_j \delta_{dj}^{IO})}$ and $Backward_j = \sum_j \frac{(Horizontal_j \delta_{jd}^{IO})}{(\sum_j) \delta_{jd}^{IO})}$ weighted by the share of sales of industry j sold to and purchased from industry d.

Table 4: Foreign ownership and sourcing behaviour in each sector.

Industry	Code#
Mining, Quarrying	1
Construction	2
Manufacturing	3
Transport and storage	4
Wholesale, Retail trade and Repair of motor vehicles	5
Real estate	6
Hotels, Restaurants	7
Other services	8

Source: Author's calculation.

Table 5: Descriptive statistics by supplying to multinationals

		Supplying to multinationals	Non-supplying to multinationals
2002	ln(Capital)	5.057	3.983
	Employees	230.661	125.336
	ln(material)	9.677	8.569
	ln(Sales)	6.517	5.331
	Company age	15.541	14.498
2003	ln(Capital)	12.621	12.141
	Employees	69.057	99.284
	ln(material)	14.384	13.531
	ln(Sales)	15.322	14.567
	Company age	20.170	18.485
2005	ln(Capital)	5.84	4.99
	Employees	158.452	90.494
	ln(material)	6.71	5.64
	ln(Sales)	6.87	5.82
	Company age	16.016	15.476

Source: Author's calculation.
Note: The values are expressed in U.S dollars.

Table 6: Descriptive statistics by sourcing from multinationals

		Domestic Inputs		Imported Inputs	
		Buy from multinationals		Non-buy from multinationals	
2002	ln(Capital)	4.626	4,951	3.748	3.797
	Employees	147.415	216.013	121.711	107.432
	ln(material)	8.799	9.626	8.587	8.361
	ln(Sales)	5.568	6.397	5.367	5.124
	Company age	14.947	15.207	13.203	14.414
2003	ln(Capital)	12.067	12.775	13.490	11.311
	Employees	76.917	158.683	229.591	34.805
	ln(material)	13.564	15.130	14.574	12.964
	ln(Sales)	14.541	16.210	15.783	13.912
	Company age	18.808	20.319	18.716	17.400
2005	ln(Capital)	5.204	5.957	4.886	4.790
	Employees	106.831	164.774	72.007	74.210
	ln(material)	5.843	6.831	5.705	5.436
	ln(Sales)	6.022	7.000	5.861	5.613
	Company age	15.655	16.653	15.050	15.092

Source: Author's calculation.
Note: The values are expressed in U.S dollars.

Table 7: FDI linkages on firm's productivity - Standard and GST estimation

	GST1				GST2			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Horizontal$	-0.418	-0.387	-0.380	-0.398	0.010	0.032	0.030	0.027
	(0.256)	(0.257)	(0.256)	(0.256)	(0.226)	(0.226)	(0.225)	(0.227)
$Backward^{IO}$	2.132		9.727		0.183		11.352*	
	(3.478)		(6.216)		(3.500)		(5.840)	
$Forward^{IO}$	-1.462	1.436			0.395	3.594		
	(2.841)	(2.462)			(2.956)	(2.589)		
$Backward^{GST}$		-1.904		-10.880		-4.635		-7.015
		(3.762)		(11.628)		(3.842)		(9.945)
$Forward^{GST}$			-10.140	9.607			-11.688*	6.582
			(6.695)	(10.034)			(6.326)	(8.602)
Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry with inputs	Yes	Yes	Yes	Yes	No	No	No	No
Industry	No	No	No	No	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.4260	0.4258	0.4304	0.4270	0.3925	0.3964	0.4015	0.3928
Observation	4,168	4,158	4,168	4,158	3,579	3,579	3,579	3,579

Note: Robust standard errors are reported in parentheses. The time-fixed, country-fixed and industry-fixed effects are controlled for in all regressions.
*Significant at 10%
**Significant at 5%
***Significant at 1%

Table 8: FDI linkages on firm's productivity - Alternative measures

	GST1		GST2	
	(1)	(2)	(3)	(4)
Horizontal	-0.338	-0.301	0.061	0.129
	(0.266)	(0.270)	(0.234)	(0.239)
$Backward^{firm}$	0.037*	0.040**	0.037**	0.040**
	(0.021)	(0.021)	(0.021)	(0.017)
$Forward^{proxy-imp}$	0.081		0.096***	
	(0.077)		(0.025)	
$Forward_1^{proxy-buy}$		-0.003		-0.011
		(0.023)		(0.018)
Time	Yes	Yes	Yes	Yes
Industry with inputs	Yes	Yes	No	No
Industry	No	No	Yes	Yes
Country	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes
R-squared	0.4281	0.4255	0.4130	0.4079
Observation	3,947	3,947	3,389	3,389

Note: Robust standard errors are reported in parentheses. The time-fixed, country-fixed and industry-fixed effects are controlled for in all regressions.
*Significant at 10%
**Significant at 5%
***Significant at 1%

Table 9: Production function estimation.

	OLS	FE	CRE
	(1)	(2)	(3)
lnK	0.101***	0.063***	0.101***
	(0.006)	(0.018)	(0.006)
lnL	0.522***	0.681***	0.526***
	(0.021)	(0.045)	(0.021)
lnM	0.406***	0.208***	0.403***
	(0.021)	(0.018)	(0.020)
Time	Yes	Yes	Yes
Industry	Yes	Yes	Yes
Country	Yes	Yes	Yes
Firm	No	Yes	Yes
R-squared	0.3095	0.6792	0.6296
Observation	7,672	7,672	7,672

Note: Robust standard errors are reported in parentheses. The time-fixed and firm-fixed effects are controlled for in all regressions.
*Significant at 10%
**Significant at 5%
***Significant at 1%

Table 10: FDI linkages on firm's productivity - Pooled OLS estimation.

			12 Economies only				All Economies	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Horizontal$	0.0008	-0.047	-0.045	-0.054	0.015	0.010	-0.020	-0.014
	(0.088)	(0.089)	(0.086)	(0.086)	(0.053)	(0.053)	(0.040)	(0.040)
$Forward^{IO}$	0.332	0.115						
	(0.251)	(0.079)						
$Backward^{IO}$	-0.312		0.109	0.117				
	(0.316)		(0.097)	(0.097)				
$Backward^{firm}$		0.030***			0.030***	0.031***	0.026***	0.027***
		(0.003)			(0.003)	(0.003)	(0.002)	(0.002)
$Forward^{proxy-imp}$			0.017***		0.018***		0.031***	
			(0.006)		(0.007)		(0.007)	
$Forward^{proxy-buy}$				0.011***		0.011***		0.006**
				(0.003)		(0.003)		(0.003)
Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.7067	0.7189	0.7167	0.7168	0.7301	0.7302	0.8943	0.8940
Observation	4,168	4,000	4,110	4,110	3,947	3,947	7,258	7,258

Note: Robust standard errors are reported in parentheses. The time-fixed, country-fixed and industry-fixed effects are controlled for in all regressions.
*Significant at 10%
**Significant at 5%
***Significant at 1%

Table 11: FDI linkages on firm's productivity - Fixed-effect estimation.

	12 Economies only						All Economies	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Horizontal$	-0.123	-0.058	-0.187	-0.134	-0.042	0.011	-0.068	-0.039
	(0.244)	(0.253)	(0.253)	(0.257)	(0.251)	(0.254)	(0.182)	(0.185)
$Forward^{IO}$	0.299	0.520						
	(3.078)	(0.666)						
$Backward^{IO}$	0.475		0.971	0.938				
	(3.685)		(0.758)	(0.761)				
$Backward^{firm}$		0.046***			0.044***	0.047***	0.033**	0.036***
		(0.019)			(0.019)	(0.019)	(0.017)	(0.017)
$Forward^{proxy-imp}$			0.096		0.080		0.136***	
			(0.071)		(0.074)		(0.047)	
$Forward^{proxy-buy}$				-0.008		-0.011		-0.011
				(0.020)		(0.021)		(0.020)
Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0816	0.0908	0.0968	0.0912	0.1013	0.0982	0.1440	0.1294
Observation	4,168	4,000	4,110	4,110	3,947	3,947	7,258	7,258

Note: The time-fixed, country-fixed and industry-fixed effects are controlled for in all regressions.
*Significant at 10%
**Significant at 5%
***Significant at 1%

Table 12: FDI linkages on firm's productivity - CRE estimation.

	12 Economies only						All Economies	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Horizontal$	0.001	-0.043	-0.044	-0.053	0.017	0.011	-0.020	-0.014
	(0.086)	(0.082)	(0.084)	(0.084)	(0.053)	(0.053)	(0.040)	(0.040)
$Forward^{IO}$	0.325	0.114						
	(0.254)	(0.077)						
$Backward^{IO}$	-0.300		0.110	0.119				
	(0.320)		(0.096)	(0.096)				
$Backward^{firm}$		0.030***			0.030***	0.031***	0.026***	0.027***
		(0.003)			(0.003)	(0.003)	(0.002)	(0.002)
$Forward^{proxy-imp}$			0.017***		0.018***		0.032***	
			(0.006)		(0.007)		(0.007)	
$Forward^{proxy-buy}$				0.011***		0.011***		0.006*
				(0.003)		(0.003)		(0.003)
Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.8393	0.8531	0.8393	0.8388	0.8538	0.8529	0.8427	0.8413
Observation	4,168	4,000	4,110	4,110	3,947	3,947	7,258	7,258

Note: Robust standard errors are reported in parentheses. The time-fixed, country-fixed and industry-fixed effects are controlled for in all regressions.
*Significant at 10%
**Significant at 5%
***Significant at 1%

Table 13: Spillovers through firm's motivation and new technology acquisition by pooled OLS.

	Pooled OLS					
	(1)	(2)	(3)	(4)	(5)	(6)
$Horizontal$	-0.021	-0.013	-0.021	-0.013	-0.021	-0.012
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
$Backward^{firm}$	0.024***	0.025***	0.023***	0.025***	0.022***	0.024***
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
$Forward^{proxy-imp}$	0.035***		0.039***		0.042***	
	(0.007)		(0.010)		(0.010)	
$Forward^{proxy-buy}$		0.006*		0.005		0.004
		(0.003)		(0.004)		(0.004)
$Backward^{Motivation}$	0.024*	0.020			0.023	0.019
	(0.014)	(0.014)			(0.015)	(0.015)
$Forward^{Motivation}_{proxy-imp}$	-0.025*				-0.023	
	(0.015)				(0.016)	
$Forward^{Motivation}_{proxy-biy}$		0.018				0.018
		(0.012)				(0.012)
$Backward^{Technology}$			0.007	0.005	0.005	0.003
			(0.005)	(0.005)	(0.005)	(0.005)
$Forward^{Technology}_{proxy-imp}$			-0.019		-0.017	
			(0.012)		(0.012)	
$Forward^{Technology}_{proxy-buy}$				0.004		0.004
				(0.004)		(0.004)
Time	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.8944	0.8941	0.8943	0.8940	0.8944	0.8941
Observation	7,258	7,258	7,258	7,258	7,258	7,258

Note: Robust standard errors are reported in parentheses. The time-fixed, industry-fixed and country-fixed effects are controlled for in all regressions.
*Significant at 10%
**Significant at 5%
***Significant at 1%

Table 14: Spillovers through firm's motivation and new technology acquisition by pooled CRE.

	CRE					
	(1)	(2)	(3)	(4)	(5)	(6)
$Horizontal$	-0.021	-0.013	-0.021	-0.013	-0.021	-0.012
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
$Backward^{firm}$	0.024***	0.025***	0.023***	0.025***	0.022***	0.024***
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
$Forward^{proxy-imp}$	0.035***		0.040***		0.042***	
	(0.007)		(0.015)		(0.010)	
$Forward^{proxy-buy}$		0.006**		0.005		0.004
		(0.003)		(0.004)		(0.004)
$Backward^{Motivation}$	0.025*	0.021			0.023	0.020
	(0.014)	(0.014)			(0.015)	(0.015)
$Forward^{Motivation}_{proxy-imp}$	-0.025*				-0.023	
	(0.015)				(0.017)	
$Forward^{Motivation}_{proxy-biy}$		0.017				0.018
		(0.012)				(0.012)
$Backward^{Technology}$			0.007	0.005	0.004	0.003
			(0.005)	(0.005)	(0.005)	(0.005)
$Forward^{Technology}_{proxy-imp}$			-0.019		-0.017	
			(0.012)		(0.012)	
$Forward^{Technology}_{proxy-buy}$				0.004		0.004
				(0.004)		(0.004)
Time	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.8430	0.8411	0.8424	0.8409	0.8428	0.8409
Observation	7,258	7,258	7,258	7,258	7,258	7,258

Note: Robust standard errors are reported in parentheses. The time-fixed, industry-fixed and country-fixed effects are controlled for in all regressions.
*Significant at 10%
**Significant at 5%
***Significant at 1%

Table 15: Spillovers through Supply-Back

	Pooled OLS		CRE	
	(1)	(2)	(3)	(4)
$Horizontal$	-0.021	-0.012	-0.021	-0.012
	(0.040)	(0.040)	(0.040)	(0.040)
$Backward^{firm}$	0.027***	0.029***	0.026***	0.029***
	(0.002)	(0.003)	(0.002)	(0.003)
$Forward^{proxy-imp}$	0.035***		0.035***	
	(0.007)		(0.007)	
$Forward^{proxy-buy}$		0.007***		0.007**
		(0.003)		(0.003)
$Supply - Back$	-0.049*	-0.045**	-0.048*	-0.046**
	(0.028)	(0.020)	(0.028)	(0.020)
Time	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes
R-squared	0.8943	0.8940	0.8427	0.8412
Observation	7,258	7,258	7,258	7,258

Note: Robust standard errors are reported in parentheses. The time-fixed, industry-fixed and country-fixed effects are controlled for in all regressions.
*Significant at 10%
**Significant at 5%
***Significant at 1%

Table 16: Spillovers through Macro Stability

	Pooled OLS		CRE	
	(1)	(2)	(3)	(4)
$Horizontal$	-0.001	0.006	-0.002	0.006
	(0.041)	(0.042)	(0.041)	(0.041)
$Backward^{firm}$	0.026***	0.027***	0.026***	0.027***
	(0.002)	(0.002)	(0.002)	(0.002)
$Forward^{proxy-imp}$	0.033***		0.033***	
	(0.007)		(0.007)	
$Forward^{proxy-buy}$		0.007**		0.006**
		(0.003)		(0.003)
Political Instability	0.002	0.0004	-0.00002	0.0001
	(0.007)	(0.007)	(0.007)	(0.007)
Macro Instability	-0.018**	-0.017**	-0.018**	-0.017**
	(0.007)	(0.007)	(0.007)	(0.007)
Corruption	0.016**	0.015**	0.016**	0.015**
	(0.007)	(0.007)	(0.007)	(0.007)
Time	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes
R-squared	0.8962	0.8959	0.8345	0.8327
Observation	6,807	6,807	6,807	6,807

Note: Robust standard errors are reported in parentheses. The time-fixed, industry-fixed and country-fixed effects are controlled for in all regressions.
*Significant at 10%
**Significant at 5%
***Significant at 1%

Table 17: IV Estimations

	Two-step Production Function		Augmented Production function	
	(1)	(2)	(3)	(4)
Panel A				
Overdue	0.023	0.009	-0.064	-0.077
	(0.067)	(0.068)	(0.067)	(0.067)
Lost	-0.136***	-0.139***	-0.073***	-0.074***
	(0.027)	(0.027)	(0.028)	(0.028)
Informal Payment	-0.006	-0.010	0.026	0.024
	(0.019)	(0.019)	(0.019)	(0.019)
Panel B				
Horizontal	0.027	0.008	0.026	-0.001
	(0.054)	(0.056)	(0.080)	(0.084)
$Backward^{firm}$	0.200***	0.201***	0.397***	0.397***
	(0.049)	(0.048)	(0.147)	(0.146)
$Forward^{proxy-imp}$	-0.007		-0.017	
	(0.012)		(0.023)	
$Forward^{proxy-buy}$		0.017***		0.023***
		(0.005)		(0.009)
F-statistic	8.44***	8.61***	3.22***	3.27
(p-value)	0.000	0.000	0.0218	0.0204
Underidentification	24.277***	24.752***	9.686***	9.830***
(p-value)	0.000	0.000	0.0214	0.0201
Hansen J	5.031	5.508	0.091	0.132
(p-value)	0.0808	0.0637	0.9556	0.9360
Observation	5,858	5,858	5,858	5,858

Note: Table only reports coefficients for excluded instruments in the first stage. Instruments are overdue, Lost and Informal payment for backward linkages. All instruments are set as dummy except the variable Lost. All diagnostic tests are provided in the second part of the table. Robust standard errors are reported in parentheses. All set of time-dummy, country-dummy and sector-dummy are included.
*Significant at 10%
**Significant at 5%
***Significant at 1%