



Technology transfers, foreign investment and productivity spillovers



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ABSTRACT

This paper explores the relationship between foreign direct investment (FDI) and the productivity of host country domestic firms. We rely on a specially designed survey of over 4000 manufacturing firms in Vietnam, and separate out productivity gains along the supply chain (obtained through direct transfers of knowledge/technology between linked firms) from productivity effects through indirect FDI spillovers. In addition to identifying indirect vertical productivity spillovers from FDI, our results show that there are productivity gains associated with direct linkages between foreign-owned and domestic firms along the supply chain not captured by commonly used measures of spillovers. This includes evidence of productivity gains through forward linkages for domestic firms which receive inputs from foreign-owned firms.

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1. Introduction

Attracting foreign direct investment (FDI) is a significant policy priority in developing countries. This is so with a view to creating jobs and injecting capital into the domestic economy. Moreover, FDI often comes with new technologies and innovations. They are potentially an important source of productivity growth as they may help host country domestic industries catch up with the international technology frontier. Given the policy attention and resources invested by governments in attempting to attract FDI, establishing whether there is positive evidence of externalities or productivity spillovers from FDI has become the topic of a vast and influential empirical literature.

The basic premise underlying the existence of FDI spillovers is that foreign-invested firms are technologically superior and that knowledge is transferred through their interactions with domestic firms, which, in turn, leads to productivity improvements.¹ There are many well-explored mechanisms through which such spillovers may be realised. Horizontal, or intra-sector, spillovers are those that result from knowledge and technology used by FDI firms transferred to competing

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¹ See Caves (1974), Rodriguez-Clare (1996) and Markusen and Venables (1999) for seminal work on the theoretical underpinnings of productivity spillovers from foreign to domestic firms.

firms in the same sector. Vertical, or inter-sector, spillovers are those that transfer through the supply chain from foreign intermediate suppliers to domestic producers or more commonly from foreign-invested firms to domestic input suppliers.

Most of the recent literature in developing country contexts finds no evidence of horizontal spillovers and emphasizes vertical spillovers through backward linkages from foreign firms to domestic suppliers as the main source of productivity effects (see, for example, [Blalock and Gertler, 2008](#); [Javorcik, 2004](#); [Kugler, 2006](#)). The available evidence also suggests that the type of the foreign investor, whether a joint venture or a wholly foreign-owned firm, matters for the extent of spillovers ([Javorcik, 2004](#)).² Overall, however, the empirical literature is inconclusive as to the nature and extent of FDI spillovers. This is highlighted in review papers by [Görg and Greenaway \(2004\)](#) and [Görg and Srobl \(2001\)](#); and conclusions drawn largely depend on the specific country context, the data used, and the methods applied.

In his overview of the literature on FDI spillovers in developing countries, [Smeets \(2008\)](#) points out that technology transfers and technology spillovers are distinct, albeit related, concepts, which should be treated as such in empirical analysis. The [Giroud et al. \(2012\)](#) criticism of the current literature is that it focuses on externalities from FDI rather than on identifying the direct effects of linkages between foreign and domestic firms. In this paper we address both of these issues by considering (i) the extent to which direct linkages between domestic and foreign firms lead to productivity improvements and (ii) whether such linkages explain FDI spillovers. In other words, we separate out productivity spillovers from FDI that are due to direct linkages from other externalities.

We use panel data from a specially designed survey of over 4000 manufacturing firms in Vietnam covering the 2009–2012 period. It allows us to directly identify supply chain linkages and technology transfers between foreign and domestic firms, using a two stage econometric approach. In the first stage we estimate productivity, and subsequently we explore the relationship between productivity and direct and indirect spillovers from FDI.

Our results provide evidence for positive indirect productivity spillovers from FDI firms in downstream sectors. Similarly, there is strong evidence to suggest that a dominance of foreign firms upstream has a negative impact on the productivity of downstream domestic firms. While these results are broadly consistent with the existing body of empirical evidence, our analysis adds a new dimension to the understanding of the nature of these spillovers. We find that direct forward linkages from foreign-invested input suppliers to domestic customers are positively related to productivity. Moreover, having a direct link with an upstream FDI firm (where the link is associated with a technology transfer) mitigates part of the negative externality from the dominance of wholly-foreign owned firms in upstream sectors. Our findings suggest that the standard measures used in the literature to capture FDI spillovers do not adequately account for the effects of direct linkages or technology transfers between foreign and domestic firms.

The remainder of this paper is structured as follows. [Section 2](#) provides an overview of related literature and some background on the Vietnamese context. [Section 3](#) outlines the empirical approach, while [Section 4](#) describes the data. [Section 5](#) presents results, and [Section 6](#) concludes.

2. Related literature and country context

The argument for state intervention to attract foreign investors hinges in part on the existence of positive externalities. Technology externalities from FDI can occur through a number of different mechanisms (see [Blalock and Gertler \(2008\)](#), [Kugler \(2006\)](#) and [Javorcik \(2004\)](#) for concise overviews of the various channels). Horizontal spillovers within sectors may arise when workers move from foreign-invested firms to domestic firms, bringing with them knowledge learned. Similarly, domestic firms may observe foreign-invested firms operating in their sector and copy the technologies used. It is generally agreed, however, that intra-industry externalities of this kind are unlikely to exist. Within sectors, foreign-invested firms compete with domestic firms and so have every incentive to prevent their embodied knowledge and technologies from leaking to their domestic competitors ([Javorcik, 2004](#)). Indeed, there is a large body of empirical literature that has been unable to find robust evidence for productivity gains accruing to domestic firms through horizontal spillovers.³

In contrast, spillovers between sectors may be more likely to occur. Spillovers through vertical linkages are desirable if the productivity gains exceed those internalized through deliberate arrangements between domestic and foreign firms. [Fig. 1](#) illustrates how technology spillovers from foreign firms to domestic firms in other sectors are defined.

Backward spillovers occur when domestic firms experience productivity improvements as a result of an increase in the presence of foreign firms in downstream sectors. Such spillovers are most likely to occur where there are direct backward linkages, i.e. when domestic firms that supply inputs to foreign-owned firms experience productivity improvements. This may happen through a number of different channels, the most likely being deliberate knowledge transfers from foreign firms to domestic input suppliers.⁴ It is also possible that firms which are not directly linked with foreign firms downstream might experience productivity improvements. This could be due to domestic suppliers having greater incentives to improve the quality of their inputs or the efficiency with which they are provided due to increased competition for foreign

² There is also a literature that explores the extent to which the absorptive capacity of firms matters for the realization of spillovers ([Giroud et al., 2012](#); [Marin and Bell, 2006](#)).

³ For recent examples see [Barrios et al. \(2011\)](#), [Blalock and Gertler \(2008\)](#), [Bwaly \(2006\)](#), [Damijan et al. \(2008\)](#), [Javorcik \(2004\)](#), and [Kugler \(2006\)](#), all of whom find no evidence of horizontal spillovers.

⁴ [Moran \(2001\)](#) uses a number of different case studies to show that deliberate technology transfers of this kind are common with foreign firms often offering, for example, technical assistance, management experience or quality assurance systems to their suppliers.

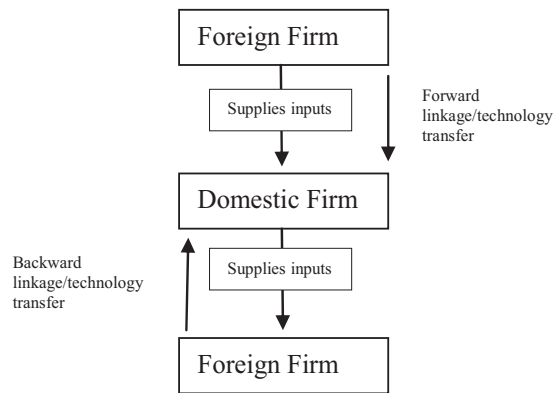


Fig. 1. Definition of FDI spillovers. Note: Direction of linkages is defined from the perspective of foreign firms.

customers, or due to scale economies reflecting greater demand for domestically-produced intermediates (Javorcik, 2004). As such, direct spillovers through linkages and indirect spillovers in the form of externalities are both likely.

It is also possible that FDI into downstream sectors may lead to negative spillovers. For example, where there are direct linkages between foreign firms and domestic input suppliers it is possible that foreign firms have more bargaining power during contract negotiations. This results in lower profits for domestic firms, which will appear as a loss in measured productivity (Girma et al., 2008). Rodriguez-Clare (1996) proposes that a pre-condition for positive spillovers through backward linkages is that domestic input suppliers produce varieties that are similar to the input requirements of the foreign firm. Accordingly, domestic firms may experience negative productivity impacts if they attempt to provide inputs they are not suited to producing.

Negative backward spillovers for domestic firms not directly linked with downstream foreign firms may also result through a competition channel. If, for example, foreign firms import intermediates, and competition from imports results in a loss in customers for domestic input suppliers, it will reduce profits for domestic upstream firms. This will negatively impact on measured productivity.⁵

Forward spillovers occur when FDI into upstream sectors impacts on the productivity of downstream domestic firms. They can also be due to direct linkages or externalities and may be positive or negative. Spillovers through direct linkages are possible if intermediates provided by foreign-invested firms embody new, more advanced technologies from which domestic firms can learn (Grossman and Helpman, 1991). Learning of this kind may as well spillover to domestic firms, not directly linked with foreign firms, if they or other domestic firms copy these inputs. In this way positive spillovers in the form of externalities are possible through this channel although they are arguably less likely. It is possible as well that inputs supplied by foreign firms may be accompanied by services or other forms of support that impact on the productivity of domestic users (Javorcik, 2004). This type of FDI spillover will only occur through direct linkages between foreign input suppliers and domestic producers.

Indirect spillovers are also possible if an increase in foreign investment in upstream sectors increases competitive pressures forcing all input suppliers in those sectors to eliminate inefficiencies (or slack) in the production process or use their inputs more efficiently to survive. As a result, downstream domestic firms that use any inputs from these sectors may experience productivity improvements due to more efficiently-produced inputs by all upstream firms. Conversely, the entry of foreign firms into upstream sectors may be anti-competitive if the foreign firm ends up holding a significant amount market share. If upstream domestic firms can no longer compete, downstream firms may have to pay higher prices for their inputs (or even suffer lower quality inputs).

Much of the recent empirical research investigating the existence of such FDI externalities in developing country contexts focuses on vertical linkages, particularly backward linkages. Some of the most notable contributions include Javorcik (2004). She finds evidence for productivity spillovers through backward linkages between domestic suppliers and partially foreign-invested customers in Lithuania during its transition period when there was a large influx of foreign investment. She finds no evidence for intra-sector spillovers or spillovers from foreign-invested input suppliers and domestic firms. Blalock and Gertler (2008) also find evidence of productivity gains among firms that supply inputs to foreign-invested firms in Indonesia. Kugler (2006) finds similar evidence for FDI spillovers that can be attributed to the outsourcing of inputs by foreign firms to domestic suppliers in Columbia. Of relevance here is that there is a particularly notable dearth of evidence in the literature on the existence of FDI spillovers through forward linkages from foreign-invested firms to domestic suppliers.

Javorcik (2004) shows that the characteristics of foreign firms may be a determining factor in the extent to which externalities from foreign firms exist. She finds that spillovers are only evident through backward linkages from partially

⁵ Aitken and Harrison (1999) propose a similar competition channel as an explanation for negative horizontal spillovers whereby foreign firms compete directly with domestic firms.

foreign-owned to domestic firms, but not from wholly foreign-owned firms. Her explanation is that the former are more likely to be better linked with the local economy through local sourcing of inputs compared to fully foreign-invested firms. Giroud et al. (2012) and Marin and Bell (2006) find that the technological activities of the foreign firms themselves may be an important determinant of whether spillovers are realised. They suggest that for policy aimed at attracting FDI to be effective in generating technology externalities, the knowledge-creation activities and technological capabilities of the foreign-invested firms as well as the extent to which they are linked with the local economy are both important considerations. Moreover, Giroud et al. (2012) generally critique the focus in the literature on externalities from FDI highlighting that it fails to identify important effects of linkages between foreign and domestic firms through, for example, direct technology transfers.

We explore these issues in the context of Vietnam, an economy whose rapid growth rate over the last decade was fuelled in part by a burgeoning local manufacturing sector and increasing levels of foreign direct investment and trade. Vietnam represents an illustrative case of economies in transition. The liberalization of the Vietnamese economy began in 1986 with the adoption of a range of policy measures under *Doi Moi* (“Renovation”), related in particular to the promotion of FDI and trade liberalization. FDI promotion was a gradual process that took place through successive revisions to investment laws between the late 1980s and the mid-2000s. Trade liberalization took the form of the removal of export taxes and non-tariff barriers and the negotiation of various trade agreements with ASEAN, the US and the EU, ultimately leading to WTO accession in 2007.

Foreign-invested firms contribute in significant ways to the Vietnamese economy, particularly in the manufacturing sector. Table 1 illustrates the contribution to output and employment of foreign-invested firms by sector between 2009 and 2012. In 2012 foreign-invested firms accounted for 55 per cent of output (revenues) and 50 per cent of employment. The variability in importance of foreign investment across sectors is also of note. Foreign-invested firms account for respectively 89 and 99 per cent of revenue and 88 and 97 per cent of employment in ISIC 2-digit sectors 15 (leather and related products) and 26 (computer, electronic and optical products). In other, more traditional, sectors such as sector 10 (food) and sector 16 (wood and wood products) they account for much less.

3. Empirical approach

3.1. Production function estimation

The first step in our analysis requires that we estimate productivity for each firm in our sample. The standard approach is to estimate a production function and use the estimated parameters to back out a firm-specific measure of productivity. OLS estimation of the production function requires that inputs are determined independently of the firm's efficiency level. This is an unrealistic assumption in most settings. It is very likely that firms' input choices are correlated with unobserved productivity shocks.

If a firm makes its variable input choices on the basis of productivity shocks that the firm, but not the econometrician observes, this leads to a bias in OLS estimates of the coefficients on these inputs in the production function. For example, firms with higher productivity may decide to employ more labour which would lead to an upward bias in the coefficient on labour if productivity is not controlled for. Labour decisions could also be countercyclical with higher productivity firms employing fewer labour inputs per unit of capital leading to a downward bias in OLS estimates of the coefficient on labour. This is consistent with the idea that more productive firms become more capital intensive. The coefficient on capital will also be biased where there is simultaneity. In both cases the bias could run in either direction.

Semi-parametric approaches which apply some structure to the underlying decision-making process of firms have become a standard way to address these concerns. The most commonly applied approaches include Olley and Pakes (1996) (OP), Levinsohn and Petrin (2003) and Akerberg et al. (2006) (ACF).⁶ Using a set of assumptions about the behaviour of firms in relation to how productivity evolves over time and the timing of input choices, these approaches correct for the endogeneity between variable inputs and unobserved productivity. Here we use ACF's modification of the OP approach. It addresses issues around the identification of the parameters in the first stage of the OP model. Moreover, we estimate the model using the Wooldridge (2009) one-step GMM estimator which is more efficient than the standard two-step procedure.

We assume a Cobb–Douglas production function written in the following form for the purpose of empirical estimation:

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + \omega_{it} + e_{it} \quad (1)$$

where y_{it} is the log of value added, l_{it} is the log of the labour input, k_{it} is the log of the capital input, ω_{it} is unobserved productivity, and e_{it} is an unanticipated shock or random error term. As in OP we assume that productivity evolves according to a first-order Markov process so

$$E(\omega_{it} | \omega_{it-1}, \omega_{it-2}, \dots, \omega_{i1}) = E(\omega_{it} | l_{it-1}) = E(\omega_{it} | \omega_{it-1}), \quad t = 2, 3, \dots, T \quad (2)$$

⁶ See Van Beveren (2010) for a full review of methods for estimating total factor productivity using firm-level data.

Table 1

Regional and sector-level contribution of foreign investors to output and employment.

Source: Authors' own calculations based on Vietnam Enterprise Survey 2009–2012.

	2009	2010	2011	2012
% Output				
All manufacturing	47.6	48.8	50.5	55.0
10: Food products	31.10	29.18	32.73	32.14
11: Beverages	59.17	48.91	50.52	50.94
12: Tobacco products	14.18	14.47	13.13	11.69
13: Textiles	58.72	57.8	62.6	64.3
14: Wearing apparel	55.6	55.6	53.8	56.2
15: Leather and related products	83.1	83.7	87.4	88.9
16: Wood and products of wood/cork	19.6	19.4	19.5	18.4
17: Paper and paper products	35.0	31.7	31.9	37.6
18: Printing and reproduction of recorded media	11.7	11.0	7.2	11.8
19: Coke and refined petroleum products	63.5	45.9	20.2	33.9
20: Chemicals and chemical products	52.3	52.3	52.5	52.3
21: Pharmaceuticals, medicinal chemicals, etc	20.3	20.8	21.8	21.3
22: Rubber and plastics products	46.5	45.7	45.0	48.6
23: Other non-metallic mineral products	30.7	28.1	26.0	25.9
24: Basic metals	25.1	29.2	31.5	31.6
25: Fabricated metal products	43.6	44.4	43.4	48.8
26: Computer, electronic and optical products	95.3	96.8	98.3	99.3
27: Electrical equipment	62.3	62.2	62.1	65.8
28: Machinery and equipment n.e.c.	46.5	55.4	57.2	68.3
29: Motor vehicles, trailers and semi-trailers	69.3	75.3	73.4	75.7
30: Other transport equipment	79.1	85.7	88.3	83.8
31: Furniture	49.3	48.6	46.3	51.7
32: Other manufacturing	57.3	86.6	86.8	88.2
% Employment				
All manufacturing	47.2	49.2	46.4	49.9
10: Food products	18.8	19.8	20.3	19.6
11: Beverages	25.5	25.8	27.8	28.7
12: Tobacco products	4.8	4.7	4.1	0.8
13: Textiles	39.5	41.0	43.7	46.4
14: Wearing apparel	58.3	57.5	56.3	57.9
15: Leather and related products	76.7	79.7	85.4	88.5
16: Wood and products of wood/cork	13.6	13.1	14.6	16.5
17: Paper and paper products	25.8	24.6	26.6	27.2
18: Printing and reproduction of recorded media	15.6	13.1	11.0	13.8
19: Coke and refined petroleum products	18.9	17.6	13.5	20.7
20: Chemicals and chemical products	28.0	30.5	30.4	32.5
21: Pharmaceuticals, medicinal chemicals, etc	17.0	19.5	18.1	19.7
22: Rubber and plastics products	49.4	50.2	49.3	50.2
23: Other non-metallic mineral products	11.3	11.1	11.7	12.0
24: Basic metals	16.1	16.8	20.1	23.1
25: Fabricated metal products	35.5	38.7	37.9	43.8
26: Computer, electronic and optical products	93.3	95.3	94.9	97.2
27: Electrical equipment	73.4	65.1	70.1	73.3
28: Machinery and equipment n.e.c.	38.5	43.6	43.4	49.0
29: Motor vehicles, trailers and semi-trailers	50.7	58.0	78.1	80.7
30: Other transport equipment	52.2	60.2	68.2	70.8
31: Furniture	46.0	45.8	46.1	49.1
32: Other manufacturing	81.3	82.6	82.1	84.5

Note: For a full description of sectors see Table A1 of the Appendix.

where I_{it-1} is the information set at time $t-1$ and all past realizations of productivity are assumed to be part of that information set. In other words, the firm expectations about future productivity depend only on the productivity in the previous period.

We assume that investment, and hence the capital stock k_{it} , is chosen at time $t-1$. This is consistent with the OP assumption about capital accumulation where capital is formed according to the following process:

$$k_{it} = (1 - \delta)k_{it-1} + i_{it-1} \quad (3)$$

where i_{it-1} is the lag of investment.

Also in accordance with OP, we assume that labour is chosen at the same time that productivity is realised.

An implication of these assumptions regarding the timing of input choices and the evolution of productivity is that:

$$\omega_{it} = f(k_{it}, i_{it}) \quad (4)$$

Assuming that $E(e_{it}|k_{it}, i_{it}) = 0$, and substituting for ω_{it} in Eq. (1) can be written as

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + f(k_{it}, i_{it}) + e_{it}, \quad t = 1, 2, \dots, T \quad (5)$$

The parameters β_l and β_k will not be separately identified, the former due to collinearity between labour and productivity (Akerberg et al., 2006) and the latter due to the inclusion of k_{it} in $f(\cdot)$.

Returning to the process assumed to underlie the evolution of productivity described in Eq. (2) we define innovation as follows:

$$\xi_{it} = \omega_{it} - E(\omega_{it}|\omega_{it-1}) \quad (6)$$

Combined with Eq. (4) which implies that $\omega_{it-1} = g(k_{it-1}, i_{it-1})$ and after some rearranging, Eq. (6) can be rewritten as

$$\omega_{it} = f[g(k_{it-1}, i_{it-1})] + \xi_{it} \quad (7)$$

Substituting into Eq. (1) provides us with a second equation which can be used to identify the two parameters of interest, β_l and β_k :

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + f[g(k_{it-1}, i_{it-1})] + v_{it}, \quad t = 2, 3, \dots, T \quad (8)$$

where $v_{it} = \xi_{it} + e_{it}$. A set of suitable moment restrictions emerges from the assumptions underlying the evolution of productivity and the timing of the choice of inputs. Eq. (6) implies that innovation will be independent of the information set at time $t-1$, i.e. ω_{it-1} . Since k_{it} is determined at period $t-1$ it will be uncorrelated with unobserved innovation ξ_{it} . In other words:

$$E(\xi_{it}|k_{it}) = 0 \quad (9)$$

Innovation will, however, be correlated with any production decisions that are made between period $t-1$ and t . As such, the labour input, determined at period t , will be correlated with ξ_{it} . The lag of labour, l_{it-1} , however, will not, given that it is part of the information set at time $t-1$. As such:

$$E(\xi_{it}|l_{it-1}) = 0 \quad (10)$$

The full set of moment conditions for (8) is therefore given by $E(v_{it}|k_{it}, l_{it-1}, k_{it-1}, i_{it-1}) = 0$. The unknown functions $f(\cdot)$ and $g(\cdot)$ are approximated by third-degree polynomials. Eq. (8) can be estimated using pooled instrumental variables estimation with the instrument set $z_{it} = (k_{it}, l_{it-1}, k_{it-1}, i_{it-1}, \dots)$, where all higher order terms and their interactions in the polynomials act as their own instruments and all lags can also be used as instruments in testing overidentifying restrictions.⁷ In the estimation of Eq. (8) a full set of time dummies is included to control for heterogeneity over time in the production function and productivity. Once we have consistent estimators for β_l and β_k , productivity can be estimated using Eq. (11).

$$\hat{\omega}_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_k k_{it} \quad (11)$$

3.2. Second stage model for FDI spillovers

Our core focus is on identifying whether there is evidence for FDI spillovers on the productivity of domestic firms and determining whether spillovers are associated with direct linkages. We begin by first establishing the extent to which we can detect positive productivity spillovers associated with FDI presence within and across sectors using standard measures applied in the literature. We follow Javorcik (2004) and consider three measures: (i) the proportion of total revenue within each 4-digit sector accounted for by foreign-owned firms to capture horizontal spillovers (Eq. (12)); (ii) the proportion of total revenue in upstream sectors accounted for by foreign-owned firms to capture forward spillovers (Eq. (13)); and (iii) the proportion of total revenue in downstream sectors accounted for by foreign-owned firms to capture backward spillovers (Eq. (14)).

$$H_{jt} = \sum_{i=1}^k R_{ijt} / \sum_{i=1}^n R_{ijt} \quad (12)$$

where k is the subset of firms that are foreign-owned and R is revenue. Firms are denoted by the subscript i , sectors by j and time by t .

$$F_{jt} = \sum_{u=1}^{J-1} \alpha_{ut} H_{ut} \quad (13)$$

⁷ Alternatively, Eqs. (5) and (8) can be estimated simultaneously using system GMM with instrument sets given by $z_{it1} = (l_{it}, k_{it}, i_{it}, \dots)$ and $z_{it2} = (k_{it}, l_{it-1}, k_{it-1}, i_{it-1}, \dots)$, respectively.

where α_{ut} is the proportion of inputs into sector j purchased from sector u in time t and H_{ut} is the proportion of foreign-owned firms in upstream sector u .

$$B_{jt} = \sum_{d=1}^{J-1} \alpha_{dt} H_{dt} \quad (14)$$

where α_{dt} is the proportion of output from sector j sold to sector d in time t and H_{dt} is the proportion of foreign-owned firms in downstream sector d .

We are interested in identifying how the change in FDI is related to the change in firm-level productivity. The challenge in identifying this effect is that there are many potential confounding factors that impact on the change in the amount of FDI into a sector and the change in the productivity of the firm. For example, FDI may be attracted to a sector that has benefited from a recent infrastructural investment. Improved infrastructure is also likely to impact on the productivity of the firm potentially confounding the effect of FDI. Including sector fixed effects goes some way towards resolving this problem, controlling for all time-invariant sector-specific factors that could influence the change in the level of FDI into a sector and the productivity path of firms in that sector. We also control for observable time-varying sector specific factors including the level of concentration of the sector, imports into the sector, and exports from the sector. We include year-dummies, which will control more generally for aggregate changes in the economic environment that could lead to both increases in FDI and improvements in firm-level productivity, and province-dummies, which control for spatial differences in the pattern of FDI and economic activity and performance.

Our baseline specification is given by⁸:

$$\Delta\omega_{ijpt} = \alpha + \eta_1 \Delta H_{jt} + \eta_2 \Delta F_{jt} + \eta_3 \Delta B_{jt} + \delta \Delta Z_{jt} + S_j + \tau_t + \pi_p + e_{ijpt} \quad (15)$$

where $\Delta\omega_{ijpt}$ is the change in productivity of firm i in sector j in province p in time t ; ΔH_{jt} , ΔF_{jt} , and ΔB_{jt} are the change in the horizontal, forward and backward indirect spillover measures defined above; Z_{jt} is a matrix of time-varying sector specific control variables; S_j are sector fixed effects; τ_t are time fixed effects; π_p are province fixed effects; and e_{ijpt} is a statistical noise term.

We add to the empirical literature which has analysed FDI spillovers by also including direct measures of linkages between domestic and FDI firms. Our data provide us with information on whether domestic firms are supplied by FDI firms or have FDI firms as customers. Moreover, we have data on whether firms receive technology transfers from their suppliers and/or customers. The availability of these data allows us to extend the analysis of FDI spillovers in two ways. First, we can examine the direct productivity impact of linkages and technology transfers. This is achieved through the estimation of Eqs. (16a) and (16b):

$$\Delta\omega_{ijpt} = \alpha + \gamma_1 FDI_{sup_{ijpt}} + \gamma_2 FDI_{cust_{ijpt}} + S_j + \tau_t + \pi_p + e_{ijpt} \quad (16a)$$

$$\begin{aligned} \Delta\omega_{ijpt} = & \alpha + \phi_1 FDI_{sup_tech_{ijpt}} + \phi_2 FDI_{sup_notech_{ijpt}} \\ & + \phi_3 FDI_{cust_tech_{ijpt}} + \phi_4 FDI_{cust_notech_{ijpt}} + S_j + \tau_t + \pi_p + e_{ijpt} \end{aligned} \quad (16b)$$

where FDI_{sup} is an indicator for whether the firm is supplied by an FDI firm and FDI_{cust} is an indicator for whether the firm has an FDI firm as a customer. The addition of 'tech' and 'notech' to the variables in Eq. (16b) signifies the disaggregation of these variables into cases where the firm received technology transfers from suppliers/customers and those that did not, respectively.

Second, we can examine the extent to which the spillover measures used in model (15) are related to direct linkages between foreign and domestic firms and technology transfers as is typically assumed to be the case in empirical studies of this kind. To test this we examine the impact of the interaction between being directly linked with foreign firms along the supply chain and the existence of FDI spillovers. We also disaggregate linkages by whether they are associated with technology transfers or not. This allows us to isolate the component of the traditional spillover measure that is due to direct linkages and direct technology transfers. The models we estimate are given in Eqs. (17a) and (17b).

$$\begin{aligned} \Delta\omega_{ijpt} = & \alpha + \eta_1 \Delta H_{jt} + \eta_2 \Delta F_{jt} + \eta_3 \Delta B_{jt} + \gamma_1 FDI_{sup_{ijpt}} + \gamma_2 FDI_{cust_{ijpt}} \\ & + \lambda_1 \Delta F_{jt} \times FDI_{sup_{ijpt}} + \lambda_2 \Delta B_{jt} \times FDI_{cust_{ijpt}} \\ & + S_j + \tau_t + \pi_p + e_{ijpt} \end{aligned} \quad (17a)$$

$$\begin{aligned} \Delta\omega_{ijpt} = & \alpha + \eta_1 \Delta H_{jt} + \eta_2 \Delta F_{jt} + \eta_3 \Delta B_{jt} \\ & + \phi_1 FDI_{sup_tech_{ijpt}} + \phi_2 FDI_{sup_notech_{ijpt}} \\ & + \phi_3 FDI_{cust_tech_{ijpt}} + \phi_4 FDI_{cust_notech_{ijpt}} \\ & + \delta_1 \Delta F_{jt} \times FDI_{sup_tech_{ijpt}} + \delta_2 \Delta F_{jt} \times FDI_{sup_notech_{ijpt}} \\ & + \delta_3 \Delta B_{jt} \times FDI_{cust_tech_{ijpt}} + \delta_4 \Delta B_{jt} \times FDI_{cust_notech_{ijpt}} \\ & + S_j + \tau_t + \pi_p + e_{ijpt} \end{aligned} \quad (17b)$$

⁸ Our productivity measure is based on a real value-added, rather than a unit output, production function. Unfortunately, we cannot directly measure average unit-value of output in our data. As a robustness-check on our results we disentangle the effects of market power through mark-ups and productivity gains by focusing on competitive sectors where individual firms lack market power so value-added closely tracks output quantities. Doing so confirms our results.

We also consider a disaggregation of foreign ownership into wholly foreign-owned and joint-venture firms.

4. Data

Our data are from four rounds of the Vietnam Technology and Competitiveness Survey (TCS) which gathered detailed information on supply chain linkages, technology transfers, and other topics for a nationally representative sample of over 4000 Vietnamese manufacturing enterprises in 2009, 2010, 2011 and 2012 (CIEM, 2011, 2012, 2013, 2014). Our sample is a sub-set of manufacturing firms covered by the Vietnam Enterprise Survey (VES) (which includes over 52,000 manufacturing enterprises) administered annually by the General Statistics Office.

The TCS survey is administered at the same time and under the same circumstances as the VES. The VES gathers balance sheet and other information on the activities of firms. The survey instruments are mailed out to firms which submit the completed questionnaires by return post to the Provincial Statistics Office. Under the Law on Statistics all firms are legally required to comply. Any firms that do not respond are contacted by provincial authorities by mail, by phone or through face-to-face visits. All data gathered is checked by the General Statistics Office for internal consistency and cross-checked with the administrative provincial data before being made available.

The TCS was included as an additional module for the sampled firms in the years under study. We match these data with information on firm activities and financial accounts gathered using the main VES instrument. This produces a rich database that allows us to explore in detail the link between productivity, technology transfers, and the underlying mechanisms at work. While we focus in the main analysis on the 2009–2012 period where we have TCS data, we match data from the TCS to the VES data from 2006–2012. In this way, we can include lags (required for the estimation of the production function) without compromising on the number of years of data we can use from the TCS sample. The caveat is that we can only include firms established since 2006. Any entrants since then will not be included. To ensure that productivity estimates are representative we use the entire VES sample in the estimation of the production functions.

The sector classification system used here is based on VSIC 2007, which corresponds closely to ISIC Revision 4. Two sectors, Sector 12, the manufacture of tobacco products, and sector 19, the manufacture of coke and refined petroleum products, are excluded due to too few firms in Vietnam operating in these sectors. The full list of manufacturing sectors and the number of firms covered by our data in each year are presented in Table A1 of Appendix A. Also shown is the number of observations on private domestic firms in our sample and the number of observations for which productivity estimates can be obtained.⁹

The output variable included in our production function is value added computed using data on profits from production activities and wages deflated using an annual GDP deflator. Capital is measured as the deflated value of assets at the beginning of the year while labour is the total number of workers employed at the end of the year. We measure assets at the beginning and the number of employees at the end of the year given the timing of the input choices assumed in the model outlined in Section 3. Investment is measured as the change in the value of fixed and long term assets over the year plus any accumulated depreciation.

Table 2 presents summary statistics for each of these variables for the entire VES sample used in the estimation of the production functions for the 2006–2012 period. On average the value added of firms in the VES sample declined between 2007 and 2011. This can be explained by the large increase in the number of firms in the sample due to a rapidly expanding domestic manufacturing sector and the decline in profits during the years of the global economic crisis. Between 2011 and 2012 value added recovered. Contractions in capital stock, labour and investment are also evident during the crisis years, while recovery followed in 2012.

Our key innovation is the inclusion of firm-level information on technology transfers to supplement the Javorcik (2004) FDI spillover measures. This responds to the Zanfei (2012) and Giroud et al. (2012) critique of the standard approach which identifies indirect spillovers from FDI rather than direct effects through intentional knowledge flows between foreign firms and domestic suppliers or customers. Accordingly, in our TCS module, firms are asked whether they are supplied inputs by (FDIsup) or supply inputs to (FDIcust) foreign-owned firms located in Vietnam. We use these indicator variables to measure direct linkages between domestic firms and foreign firms along the supply chain.

In addition, firms are asked whether contracting relationships with suppliers and customers result in technology transfers from the supplier to the enterprise. We disaggregate the indicators for direct linkages with FDI suppliers and customers by whether or not they are associated with technology transfers. So for firms that are supplied inputs by FDI firms, which also report that they receive a technology transfer from their intermediate input suppliers, we regard this as a forward technology transfer from an FDI producer of intermediate inputs to the firm (FDIsup_tech); and we distinguish these from firms that have FDI suppliers but do not receive technology transfers (FDIsup_notech). Similarly, for firms which report they have contracting relationships with customers which lead to technology transfers and simultaneously have FDI firms as customers we regard this as a backward technology transfer from an FDI customer to the firm (FDIcust_tech); and we distinguish this from firms that have FDI customers but do not receive technology transfers from them (FDIcust_notech).

⁹ A caveat of using our semi-parametric approaches is that it requires that firms have positive levels of investment and so firms with zero investment are excluded. This accounts for 10 per cent of the full VES sample.

Table 2

Summary statistics for production function variables.

VES sample	2006 <i>n</i> = 9161		2007 <i>n</i> = 10,633		2008 <i>n</i> = 12,317		2009 <i>n</i> = 15,810		2010 <i>n</i> = 17,799		2011 <i>n</i> = 18,688		2012 <i>n</i> = 15,956	
<i>Production function</i>	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Value added	3918	24,244	4024	21,332	3411	19,954	3406	26,350	3336	24,979	2431	24,408	4753	56,747
Capital	21,971	121,968	21,467	112,497	19,907	103,818	19,021	115,847	18,775	117,924	13,510	95,517	24,832	164,325
Labour	186	895	178	833	160	853	124	683	115	494	84	338	137	556
Investment	6125	41,033	6580	42,854	6059	47,590	4828	41,632	4959	47,857	3202	32,890	6102	53,688

Descriptive statistics for each of these variables are provided in Table 3. We present the means for the sample of private domestic firms (79 per cent of the TCS sample) we use in our analysis and also for foreign firms (19 per cent of the TCS sample) for comparison purposes. Approximately 16 per cent of private domestic firms reported that they were supplied inputs by a foreign-owned firm at some point during the sample period. This can be compared with almost 77 per cent of foreign-owned firms in our sample. Around half of the inputs supplied by FDI firms to downstream private domestic firms is associated with technology transfers. The extent of linkages between private domestic firms and downstream FDI firms is reflected in over 26 per cent of private domestic firms selling their output to FDI firms. A smaller proportion, around one-third, is associated with technology transfers. Some 70 per cent of foreign-owned firms report that they sell their output to downstream FDI firms with only around 21 per cent of these being associated with technology transfers.

Summary statistics for the sector specific spillover measures are also presented in Table 3. These measures are computed as defined in Eq. (12) for horizontal spillovers, Eq. (13) for vertical spillovers through forward linkages, and Eq. (14) for vertical spillovers through backward linkages. They can be interpreted as the proportion of revenue, on average, generated by foreign-invested firms in the same sector in the case of (12), in upstream sectors in the case of (13) and in downstream sectors in the case of (14). Linkages for the vertical spillover measures are constructed using the Vietnam Supply-Use Tables (SUT) for 2007. The SUT maps the use of 138 commodities in 112 production activities.¹⁰ We link these production activities to the 4-digit ISIC codes used in the VES to produce 42 comparable sector codes. The SUT data are used to construct the weights in Eqs. (13) and (14) that capture linkages between sectors.

To illustrate, for linkages with upstream sectors (i.e. α_{ut} in Eq. (13)), for each (SUT) sector j , their link with upstream (SUT) sector u is the proportional contribution of output from sector u to its total input base. Similarly for linkages with downstream sectors (i.e. α_{dt} in Eq. (14)), for each (SUT) sector j , their link with downstream (SUT) sector d is the proportional contribution of output from sector j to the input base of sector d . These weights are used to compute a weighted average of foreign dominance in upstream and downstream sectors, respectively.¹¹ Also presented in Table 3 are the foreign dominance measures for wholly foreign-owned firms and joint ventures.¹²

As an example of the kind of linkages we identify consider the 2-digit ISIC sector 10, namely food products. The SUT weights (not shown) suggest that one of the main suppliers of the food products and beverages sector is the chemicals and chemical products sector (sector 20). Inputs from chemicals and chemical products are likely to be in the form of additives or preservatives. Now, take a case where there is a dominance of foreign firms supplying chemicals and chemical products to domestic producers of food and beverages. This could result in productivity spillovers due to forward linkages if foreign firms offer new varieties of preservatives or additives, not available from domestic producers, leading to more efficient production by domestic downstream food producers.

If the above spillover is due to a direct linkages or technology transfers it will be picked up in our firm specific measures. If not, it will appear as an indirect spillover effect. On the other hand if there is a dominance of foreign-owned firms in the food products sector supplied by domestic producers of chemicals and chemical products we might expect to see productivity spillovers through backward linkages if the foreign-owned food producers provide domestic producers of chemicals with new technologies to improve their production techniques or quality standards. As for forward linkages, if the spillover is due to direct linkages or technology transfers it will be picked up in our firm-specific measures. If not, it will appear as a positive externality through the backward indirect spillover measure.

Each of the sector-level measures is computed using the full census of manufacturing firms included in the VES. We also include a control for sector-level concentration measured at the 4-digit sector level using the standard Herfindahl–

¹⁰ See Arndt et al. (2010) for a full description of the 2007 social accounting matrix for Vietnam and details of its construction.

¹¹ Recent work by Barrios et al. (2011) highlights the potential measurement problems in using weights of this kind to measure linkages between downstream foreign affiliates and upstream domestic firms given that the former are likely to have a different pattern of input sourcing. They propose that using home country input-output tables to construct these weights is a more accurate approach. Unfortunately, we do not have data on the country of origin of the foreign affiliates and so cannot use this approach. It will not, however, affect our measure of linkages between downstream domestic firms and upstream foreign affiliates.

¹² It should be noted that while these measures do not appear to vary much on average over time, within sectors there is a significant amount of variation across the years.

Table 3

Summary statistics for second stage empirical analysis.

TCS sample	n=4278		n=4258		n=4112		n=3158	
<i>Ownership types</i>								
Private	77.82		78.77		78.84		79.86	
Foreign	19.50		19.28		18.99		18.18	
State	2.69		1.95		2.16		1.96	
	Private	Foreign	Private	Foreign	Private	Foreign	Private	Foreign
<i>Linkages</i>								
FDI supplier	17.48		16.96		15.39		15.50	
With technology transfer	8.17		8.47		8.20		7.89	
No technology transfer	9.31		8.50		7.19		7.61	
FDI customer	26.19		27.19		25.85		27.12	
With technology transfer	8.71		9.51		9.25		9.99	
No technology transfer	17.48		17.68		16.59		17.12	
<i>FDI Spillovers^a</i>								
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Horizontal	0.40	0.20	0.41	0.21	0.41	0.20	0.42	0.21
Forwards	0.38	0.17	0.40	0.17	0.37	0.19	0.41	0.19
Forwards JV	0.11	0.06	0.11	0.05	0.08	0.04	0.08	0.05
Forwards 100%	0.27	0.17	0.30	0.18	0.30	0.19	0.33	0.19
Backwards	0.41	0.13	0.41	0.14	0.43	0.13	0.43	0.14
Backwards JV	0.15	0.08	0.14	0.34	0.13	0.08	0.11	0.07
Backwards 100%	0.26	0.14	0.27	0.14	0.30	0.12	0.33	0.13
<i>Sector characteristics^a</i>								
Sector concentration	0.07	0.12	0.05	0.08	0.04	0.06	0.04	0.06
Log exports	11.44	2.83	11.72	2.55	11.72	2.62	11.83	2.57
Log imports	11.01	2.66	11.26	2.37	11.10	2.51	11.06	2.48

^a Computed using full VES sample in each year.

Hirschman Index (HHI), constructed as

$$HHI_{jt} = \sum_{i=1}^n rs_{ijt}^2 \quad (18)$$

where rs_{ijt} is the revenue share of firm i in sector j at time t . As shown in Table 3 this measure averages around 0.05 suggesting a high degree of competition within the sectors included in our analysis.

Controls for the level of imports and exports from each 4-digit sector are also included. Data for these variables are taken from the UN COMTRADE database available through World Integrated Trade Solutions on the value of exports and imports for 4-digit ISIC sectors for Vietnam with the rest of the world.

5. Results

5.1. Productivity estimation

The first step of our empirical approach is to estimate firm-level productivity. Using the approach outlined in Section 2 we estimate production functions separately for sub-sectors of manufacturing.¹³ We use the full sample of firms from the VES in estimating productivity as the larger sample is more representative and will provide more accurate estimates of the production function parameters. The coefficient estimates are presented in Table 4.

In all cases tests for weak identification, underidentification and the first stage F -tests confirm the validity of the instruments.¹⁴ We use higher order terms of the instruments or additional lags to test for overidentification. For some sectors we find the lag of labour to be an unsuitable instrument for current period labour. In these cases we use a higher order term of the lag of labour or the second lag as the instrument. The final specification is an exactly identified system to avoid loss of data due to the inclusion of additional lags but the results do not change much when we use different combinations of valid overidentifying restrictions. Details of the instrument used in each sector and the instrument used to test for the overidentifying restrictions are provided in Table 4.

We also present in Table 4 the estimates from OLS estimation and using the standard OP approach. In all cases the coefficient on capital is lower when the production function is estimated using our preferred approach as compared with

¹³ Sectors are divided into 2-digit sub-sectors for the purpose of estimating productivity. Some are grouped together due to the fact that there are too few firms in some sectors. The groupings are indicated in Table A1 of Appendix A.

¹⁴ In the table we present p -values for each test. The underidentification test is based on the Kleibergen–Paap rk LM statistic, the weak identification test is based on the Cragg–Donald Wald F statistic, the F -test is based on Angrist–Pischke multivariate F -test of excluded instruments in the first stage, and the test for the overidentifying restrictions is based on Hansen's J test.

Table 4

Production function estimates.

	Wooldridge	OP	OLS		Wooldridge	OP	OLS
VSIC 10-11				VSIC 16			
<i>l</i>	0.699*** (0.019)	0.727*** (0.008)	0.752*** (0.012)	<i>l</i>	0.890*** (0.022)	0.852*** (0.010)	0.870*** (0.016)
<i>k</i>	0.275*** (0.022)	0.310*** (0.060)	0.414*** (0.007)	<i>k</i>	0.251*** (0.026)	0.293*** (0.026)	0.338*** (0.009)
Instrument for <i>l</i>	lag_1 ²			lag_1			
Observations	10,622	8404	10,622	Observations	4778	3661	,778
RTS	0.974	1.037	1.166	RTS	1.141	1.145	1.208
Under ident.	0.000			Under ident.	0.000		
Weak ident.	0.000			Weak ident.	0.000		
<i>F</i> -test of exl. inst.	0.000			<i>F</i> -test of exl. inst.	0.000		
Hansen <i>J</i> statistic	0.740			Hansen <i>J</i> statistic	0.201		
Extra instrument	lag2_1			Extra instrument	lag2_1		
VSIC 13				VSIC 17			
<i>l</i>	0.834*** (0.025)	0.779*** (0.014)	0.815*** (0.022)	<i>l</i>	1.055*** (0.036)	0.911*** (0.017)	0.978*** (0.027)
<i>k</i>	0.196*** (0.034)	0.350*** (0.067)	0.357*** (0.012)	<i>k</i>	0.096*** (0.037)	0.128* (0.076)	0.280*** (0.014)
Instrument for <i>l</i>	lag_1			lag_1			
Observations	2799	1975	2799	Observations	2939	2197	2939
RTS	1.030	1.129	1.172	RTS	1.151	1.039	1.258
Under ident.	0.000			Under ident.	0.000		
Weak ident.	0.000			Weak ident.	0.000		
<i>F</i> -test of exl. inst.	0.000			<i>F</i> -test of exl. inst.	0.000		
Hansen <i>J</i> statistic	0.678			Hansen <i>J</i> statistic	0.250		
Extra instrument	lag_1 ²			Extra instrument	lag2_1		
VSIC 14				VSIC 18			
<i>l</i>	1.012*** (0.017)	0.921*** (0.009)	0.892*** (0.014)	<i>l</i>	0.867*** (0.029)	0.863*** (0.014)	0.767*** (0.021)
<i>k</i>	0.067** (0.028)	0.174*** (0.054)	0.306*** (0.011)	<i>k</i>	0.204*** (0.025)	0.230*** (0.027)	0.427*** (0.012)
Instrument for <i>l</i>	lag_1			lag_1			
Observations	4062	2794	4062	Observations	2469	1650	2469
RTS	1.079	1.095	1.288	RTS	1.071	1.093	1.194
Under ident.	0.000			Under ident.	0.000		
Weak ident.	0.000			Weak ident.	0.000		
<i>F</i> -test of exl. inst.	0.000			<i>F</i> -test of exl. inst.	0.000		
Hansen <i>J</i> statistic	0.130			Hansen <i>J</i> statistic	0.418		
Extra instrument	lag_1 ²			Extra instrument	lag_1 ²		
VSIC 15				VSIC 20-21			
<i>l</i>	0.903*** (0.031)	0.890*** (0.018)	0.830*** (0.025)	<i>l</i>	0.612*** (0.043)	0.709*** (0.020)	0.736*** (0.033)
<i>k</i>	0.173** (0.077)	0.076 (0.083)	0.332*** (0.017)	<i>k</i>	0.382*** (0.049)	0.518*** (0.036)	0.466*** (0.016)
Instrument for <i>l</i>	lag_1			lag_1 ²			
Observations	1139	835	1139	Observations	2812	2032	2812
RTS	1.076	0.966	1.162	RTS	0.994	1.227	1.202
Under ident.	0.000			Under ident.	0.000		
Weak ident.	0.000			Weak ident.	0.000		
<i>F</i> -test of exl. inst.	0.000			<i>F</i> -test of exl. inst.	0.000		
Hansen <i>J</i> statistic	0.119			Hansen <i>J</i> statistic	0.137		
Extra instrument	lag_1 ²			Extra instrument	lag_1 ³		
VSIC 22				VSIC 26-28			
<i>l</i>	0.849*** (0.027)	0.788*** (0.013)	0.791*** (0.021)	<i>l</i>	0.736*** (0.038)	0.769*** (0.015)	0.788*** (0.030)
<i>k</i>	0.264*** (0.029)	0.329*** (0.055)	0.384*** (0.011)	<i>k</i>	0.228*** (0.043)	0.382*** (0.066)	0.365*** (0.026)
lag_1				lag2_1			
Observations	4429	3169	4429	Observations	2481	2471	2481
RTS	1.112	1.117	1.175	RTS	0.964	1.151	1.153
Under ident.	0.000			Under ident.	0.000		
Weak ident.	0.000			Weak ident.	0.000		
<i>F</i> -test of exl. inst.	0.000			<i>F</i> -test of exl. inst.	0.000		
Hansen <i>J</i> statistic	0.394			Hansen <i>J</i> statistic	0.240		
Extra instrument	lag_1 ²			Extra instrument	lag2_k		
VSIC 23				VSIC 29, 30, 32			
<i>l</i>	0.877***	0.833***	0.839***	<i>l</i>	0.733***	0.823***	0.879***

Table 4 (continued)

	Wooldridge	OP	OLS		Wooldridge	OP	OLS
<i>k</i>	(0.025) 0.198*** (0.033)	(0.012) 0.286*** (0.014)	(0.019) 0.359*** (0.011)	<i>k</i>	(0.044) 0.238*** (0.046)	(0.016) 0.346*** (0.054)	(0.031) 0.294*** (0.026)
lag_1				lag2_1			
Observations	5408	4349	5408	Observations	2027	2053	2027
RTS	1.075	1.119	1.198	RTS	0.971	1.169	1.173
Under ident.	0.000			Under ident.	0.000		
Weak ident.	0.000			Weak ident.	0.000		
<i>F</i> -test of exl. inst.	0.000			<i>F</i> -test of exl. inst.	0.000		
Hansen <i>J</i> statistic	0.327			Hansen <i>J</i> statistic	0.928		
Extra instrument	lag2_1			Extra instrument	lag2_1		
VSIC 24–25				VSIC 31			
<i>l</i>	0.807*** (0.028)	0.839*** (0.009)	0.888*** (0.019)	<i>l</i>	0.997*** (0.023)	0.930*** (0.011)	0.835*** (0.017)
<i>k</i>	0.232*** (0.023)	0.179*** (0.043)	0.295*** (0.016)	<i>k</i>	0.134*** (0.029)	0.167*** (0.036)	0.339*** (0.011)
lag2_1				lag_1			
Observations	6440	6895	6440	Observations	4083	3077	4083
RTS	1.039	1.018	1.183	RTS	1.131	1.097	1.174
Under ident.	0.000			Under ident.	0.000		
Weak ident.	0.000			Weak ident.	0.000		
<i>F</i> -test of exl. inst.	0.000			<i>F</i> -test of exl. inst.	0.000		
Hansen <i>J</i> statistic	0.120			Hansen <i>J</i> statistic	0.968		
Extra instrument	lag2_1			Extra instrument	lag_1 ²		

Note: Robust standard errors are presented in parenthesis. *P*-values for underidentification test is based on the Kleibergen–Paap rk LM statistic, weak identification test is based on the Cragg–Donald Wald *F* statistic, *F*-test is based on Angrist–Pischke multivariate *F*-test of excluded instruments in the first stage, and the test for the overidentifying restrictions is based on Hansen's *J* test. Sectors 21–22, 30–33 and 34–35 are combined in estimating productivity due to small number of observations in some sectors. The implication of this is that they are assumed to have common production functions.

*** *p* < 0.01.

OLS. This makes sense if we expect firms' capital choices to be positively correlated with productivity suggesting that OLS would lead to an upward bias in the capital coefficient. The coefficient on labour is also lower for some sectors, suggesting that in these sectors there is a positive correlation between labour and productivity leading to an upward bias in the labour coefficient when using OLS. It is, however, higher in others, suggesting that in these sectors there is a negative correlation between labour and productivity. This is consistent with the idea that more productive firms employ fewer units of labour per unit of output.

The OP parameters in general appear to under-correct for the extent of the bias in the labour and capital coefficients. In some cases (5 out of 14) OP estimates the bias on the labour coefficient to be in the opposite direction to what we find using our approach. This is consistent with the idea that the identification of the labour coefficient in the first stage is hampered by multicollinearity as explained by [Akerberg et al. \(2006\)](#). Overall, returns to scale is lowest when using our approach suggesting that OLS and OP lead to an underestimation of productivity. We base the second stage of our analysis on the productivity estimates obtained using our approach to estimating the production function parameters. We present the results using the OP approach later as a robustness check.

Average productivity (estimated using our approach) for each sector and the growth trajectory for the 2008–2012 period are presented in [Table 5](#). Average productivity levels across sectors cannot be compared given that the production functions are estimated separately for each sector thus implicitly assuming that firms within sectors share a common technology but that this technology is different between sectors. The productivity trajectory in each sector can be compared. It should be noted that changes in productivity over time may be due to real productivity changes or the entry and exit of firms given that we are working with an unbalanced panel of firms.

Some sectors experienced declines in productivity over the period. They include, most notably, sectors 10–11 (food products and beverages), sector 16 (wood and wood products), sector 18 (printing and production of recorded media), sector 20–21 (chemicals and chemical products and pharmaceuticals, etc), 23 (other non-metallic mineral products), and sector 24–25 (basic and fabricated metals). Sectors experiencing the fastest productivity growth include sector 15 (leather and related products), sector 22 (rubber and plastics) and sector 32 (furniture).

5.2. FDI spillovers

The overall aim of our analysis is to determine the extent to which the productivity of firms is related to FDI, considering both direct and indirect effects. To explore these effects we use the sub-sample of firms included in the TCS dataset for

Table 5

Estimated average productivity and productivity growth 2009–2012.

2-digit sector	Average	Productivity growth			
	Productivity	2009	2010	2011	2012
10–11	1.322	100.00	96.18	94.16	91.27
13	1.585	100.00	110.07	105.80	106.67
14	1.895	100.00	106.72	106.06	104.85
15	1.563	100.00	126.08	121.06	128.29
16	0.755	100.00	95.84	96.73	87.53
17	1.598	100.00	109.58	103.57	109.32
18	1.626	100.00	97.27	90.42	89.73
20–21	1.251	100.00	100.71	99.76	92.92
22	1.074	100.00	100.87	98.84	115.36
23	1.274	100.00	96.55	88.72	80.68
24–25	1.447	100.00	98.88	93.07	90.03
26–28	1.937	100.00	98.64	93.86	97.68
29, 30, 32	1.829	100.00	101.61	98.22	106.61
32	1.353	100.00	107.58	101.16	109.90

which we have information on direct linkages and technology transfers. We begin by estimating the baseline specification for indirect spillovers given in Eq. (15) which is the typical specification used in empirical studies of this kind. Results are presented in Table 6.¹⁵

We find no evidence to suggest that there are horizontal spillovers or externalities associated with operating in a sector with a large presence of foreign-owned firms. This is consistent with findings of other empirical studies (Barrios et al., 2011; Blalock and Gertler, 2008; Bwaly, 2006; Damijan et al., 2008; Javorcik, 2004; Kugler, 2006) and suggests that foreign firms have an incentive to protect their technology and know-how and prevent it from leaking to competitors, as highlighted by Javorcik (2004).

Focussing on vertical spillovers we find strong evidence for negative forward spillovers from a dominance of FDI in upstream sectors on the productivity of domestic downstream firms that purchase inputs from these sectors. Negative spillovers are associated with both joint venture and wholly foreign-owned firms (column 2). Javorcik (2004) also finds some evidence of negative forward spillovers, but not to the same magnitude as here, or as well determined.

There is evidence of positive backward spillovers from downstream sectors with a dominance of foreign-owned firms to upstream domestic firms supplying inputs to those sectors. This is also consistent with findings in other empirical studies (Javorcik, 2004; Blalock and Gertler, 2008; Kugler, 2006). Moreover, in column 2, we find that this positive spillover is associated with a dominance of joint ventures between foreign-owned firms and Vietnamese firms (either state or privately-owned). Javorcik (2004) finds that backward spillovers are only evident from partially-owned foreign firms in the Lithuanian case.

Our results for the Vietnamese case are as noted consistent with the findings of other similar empirical studies. It is difficult, however, on the basis of these findings, to say anything about the underlying mechanisms at work. As highlighted in Section 2, in the case of positive backward spillovers from downstream foreign firms to domestic firms, we cannot say – based on the analysis so far – whether (i) these spillovers are due to direct knowledge and/or technology transfers to domestic firms linked with foreign firms along the supply chain, or (ii) they are due to indirect spillovers in the form of, for example, efficiency improvements due to increased competition among domestic input suppliers competing for foreign customers or scale economies due to a greater demand for domestically produced inputs.¹⁶

Negative spillovers from upstream foreign firms to domestic firms in downstream sectors could also be due to negative effects associated with direct linkages between domestic firms and foreign input suppliers. This includes for example domestic firms which are locked into using inputs purchased from FDI firms because of high sunk costs or asymmetric bargaining power in the negotiation of input contracts if FDI firms have a dominant position upstream. They could also be due to negative indirect externalities such as foreign-owned firms gaining market power in upstream sectors.

To disentangle the above effects we focus on the impact of direct linkages between FDI firms and domestic firms along the supply chain on productivity and the extent to which firms report that they experience technology transfers through these links. Using the firm level indicators described in Section 4, we estimate the model given in Eq. (16a). The results are presented in column 1 of Table 7.

We include the firm specific indicators of linkages along with the same set of sector control variables, year, sector and province fixed effects. We find a positive and well-determined relationship between being linked with an FDI firm upstream

¹⁵ Here and throughout, we report clustered standard errors at the sector-year level.

¹⁶ We also explored possible additional mechanisms by estimating a range of models that interacts the backward indirect spillover measure with various firm characteristics. We find some evidence that the positive spillover from downstream FDI firms is associated with firms that expand production into other sectors or change sector altogether. This is consistent with Newman et al. (2013) who find that firms tend to switch into sectors where there are opportunities for productivity gains. Results (not presented) are available on request.

Table 6
Impact of indirect FDI spillovers on productivity.

	(1)	(2)
<i>Indirect spillovers</i>		
Horizontal	0.010 (0.117)	–0.010 (0.117)
Forward	–0.846*** (0.131)	
Forward JV		–0.701* (0.370)
Forward 100% for		–0.839*** (0.158)
Backward	0.486** (0.213)	
Backward JV		0.638** (0.278)
Backward 100% for		0.388 (0.240)
<i>Sector controls</i>		
lnexp	–0.005 (0.011)	–0.005 (0.011)
lnimp	–0.001 (0.010)	–0.001 (0.010)
HHI4	0.085* (0.046)	0.081* (0.047)
R ²	0.031	0.031
Firms	4248	4248
Obs	10,144	10,144

Note: Each model is estimated using first differences and includes time, sector and province fixed effects. Robust standard errors clustered at the sector-time level are presented in parenthesis.

* $p < 0.10$.

** $p < 0.05$.

*** $p < 0.01$.

and the productivity of the downstream domestic producer. This is in contrast to the indirect spillover measure which suggests that there are negative indirect externalities associated with a dominance of FDI firms upstream. Despite a large theoretical literature proposing reasons as to why productivity spillovers through forward linkages might exist (see Section 2) there is little empirical evidence to suggest that they are an important source of productivity growth for domestic firms in developing countries. Although some care should be exercised in inferring causality, our results suggest that, at least in the Vietnamese case, forward linkages are a source of productivity growth. This is only so for domestic firms which are directly linked with FDI firms through the supply chain.¹⁷ In contrast, we do not find any evidence to suggest that direct linkages with downstream FDI customers are related to the productivity of domestic firms.

To quantify the magnitude of the contrasting effects of direct and indirect spillovers through the forward spillover channel we focus on the interpretation of the negative coefficient on forward indirect spillovers in column (1) of Table 6 and the positive coefficient on forward direct linkages in column (1) of Table 7. In the case of the former, the coefficient indicates that a one percentage point increase in the proportion of inputs into a sector that are supplied by foreign-owned firms will, on average, lead to a 0.00846 unit decrease in the level of productivity of firms in that sector.¹⁸ This is equivalent to a decline in productivity of 0.6 per cent.¹⁹ Over the entire sample period indirect forward spillovers increased by 3.4 percentage points. Our results suggest that, all else equal, this would lead to a reduction in productivity of 2.2 per cent. Given that productivity over the period fell by 11.7 per cent for all firms this is not a negligible amount. The coefficient on forward direct linkages in column (1) of Table 7 suggests that the average year-on-year change in productivity was 0.048 units, or 3.7 percentage points, higher for firms that have an FDI supplier. This should be considered alongside the fact that the average year-on-year change in productivity was –0.02 for firms that do not have an FDI supplier. As such, while productivity was

¹⁷ We also estimate the model including a range of interaction terms between the direct forward linkage measure and indicators of firm behaviour. We find some evidence that the productivity impact of direct forward linkages is related to an expansion of products and varieties by downstream firms. This (tentatively) suggests that one channel through which purchasing inputs from foreign-owned firms impacts on productivity is that it leads to within-firm changes in the types of products produced. Results (not presented) are available on request.

¹⁸ We divide the coefficient by 100 due to the way in which the indirect forward spillovers measure is constructed. The estimated coefficient captures the impact of a one unit increase in the indirect forward spillover measure on the average change in the productivity level of firms. A one unit increase in the indirect forward spillover measure is equivalent to a 100 percentage point increase in the proportion of inputs supplied by foreign-owned firms. We divide by 100 to get a one percentage point increase.

¹⁹ In comparison, the positive coefficient on the indirect backward spillover measures suggests that a one percentage point increase in the proportion of FDI firms in downstream sectors, all else equal, would lead to a 0.4 per cent increase in productivity.

Table 7

Impact of direct FDI linkages on productivity and interaction with indirect spillovers.

	(1)	(2)	(3)
<i>Direct linkages</i>			
Forward Linkage	0.048** (0.021)	0.049** (0.021)	0.046** (0.022)
Backward linkage	0.002 (0.016)	0.003 (0.016)	0.017 (0.018)
<i>Indirect spillovers</i>			
Horizontal		0.009 (0.114)	–0.005 (0.116)
Forward		–0.896*** (0.160)	
Forward JV			–0.688 (0.427)
Forward 100% for			–0.916*** (0.185)
Backward		0.437* (0.231)	
Backward JV			0.446 (0.313)
Backward 100% for			0.426* (0.256)
<i>Spillovers interactions</i>			
For: Linkage × Spillover		0.253 (0.254)	
For JV: Linkage × Spillover			–0.045 (0.591)
For 100: Linkage × Spillover			0.357 (0.291)
Back: Linkage × Spillover		0.245 (0.343)	
Back JV: Linkage × Spillover			0.742* (0.426)
Back 100: Linkage × Spillover			–0.052 (0.376)
R^2	0.025	0.031	0.032
Firms	4248	4248	4248
Obs	10,144	10,144	10,144

Note: Each model is estimated using first differences and includes time, sector and province fixed effects. Time varying sector-level control variables included in Table 5 are also included here but are not presented for ease of exposition. They are available on request. Robust standard errors clustered at the sector-time level are presented in parenthesis.

* $p < 0.10$.

** $p < 0.05$.

*** $p < 0.01$.

declining for firms that were not supplied by an FDI firm, it was increasing for those firms that were. This suggests that spillovers through direct linkages are an important source of productivity growth.

We extend the model to consider the impact of the interaction between being directly linked with foreign firms along the supply and the indirect FDI spillover measure. This allows us to consider to what extent the effect of the traditional spillover measures is due to direct linkages or indirect effects. We estimate the model given in Eq. (17a) which includes interactions between the traditional spillover measures and the firm specific linkage measures. The results are presented in column 2 of Table 7 for FDI spillovers as a whole and in column 3 for FDI spillovers disaggregated by joint venture and wholly foreign-owned firms. The interaction terms are not well determined in either case.²⁰ We do not find any evidence that the negative indirect spillover associated with a dominance of upstream foreign-owned firms is mitigated by being directly supplied by these firms, although the positive productivity impact through the direct linkage channel remains.

In Table 8 we disaggregate the direct linkages between firms along the supply chain by whether or not they are associated with a transfer of technology (Eqs. (16b) and (17b)). As revealed in column 1 the positive productivity association with having FDI suppliers (i.e. a forward direct linkage) is not associated with receiving technology transfers from upstream firms. Positive impacts on productivity through direct linkages with upstream firms may be due to a number of other factors as discussed in Section 2. For example, they could emerge from the possibility that inputs from foreign firms embody better technology or are of a higher quality (Grossman and Helpman, 1991; Girma et al., 2008), or that inputs from foreign firms are

²⁰ In column 3 we find some, albeit weak, evidence that the positive spillover from joint venture FDI firms is associated with firms that are directly linked with domestic customers. The coefficient on the interaction term is only marginally significant, however, and so we do not place much weight on this finding.

Table 8

Impact of direct FDI linkages on productivity and interaction with indirect spillovers – accounting for technology transfers.

	(1)	(2)	(3)
<i>Direct linkages</i>			
Forward linkage with tech transfer	0.039 (0.024)	0.040 (0.025)	0.030 (0.026)
Forward linkage no tech transfer	0.055** (0.026)	0.057** (0.026)	0.059** (0.026)
Backward linkage with tech transfer	0.006 (0.027)	0.006 (0.027)	0.007 (0.031)
Backward linkage no tech transfer	0.001 (0.018)	0.002 (0.017)	0.020 (0.020)
<i>Indirect spillovers</i>			
Horizontal		0.009 (0.115)	0.001 (0.116)
Forward		–0.898*** (0.161)	
Forward JV			–0.687 (0.428)
Forward 100% for			–0.921*** (0.187)
Backward		0.436* (0.231)	
Backward JV			0.444 (0.314)
Backward 100% for			0.426* (0.258)
<i>Spillovers interactions</i>			
For: linkage with tech transfer × spillover		0.356 (0.272)	
For: Linkage no Tech Transfer × spillover		0.149 (0.302)	
For JV: Linkage with Tech Transfer × spillover			–0.492 (0.584)
For 100: Linkage with tech transfer × spillover			0.602** (0.281)
For JV: Linkage no tech transfer × spillover			0.287 (0.707)
For 100 Linkage no tech transfer × spillover			0.109 (0.350)
Back: Linkage with tech transfer × spillover		0.330 (0.596)	
Back: Linkage no tech transfer × spillover		0.202 (0.334)	
Back JV: Linkage with tech transfer × spillover			0.344 (0.699)
Back 100: Linkage with tech transfer × spillover			0.331 (0.713)
Back JV: Linkage no tech transfer × spillover			0.887* (0.492)
Back 100: Linkage no tech transfer × spillover			–0.213 (0.358)
R ²	0.025	0.031	0.032
Firms	4248	4248	4248
Obs	10,144	10,144	10,144

Note: As in Table 7.

accompanied by support services that impact positively on the productivity of downstream domestic firms (Javorcik, 2004). Our findings suggest that, in the Vietnamese case, it is not due to a deliberate transfer of new technology or know-how from the FDI firm.

In columns 2 and 3 of Table 8 we include interaction terms between the direct linkage and technology transfer measures and the FDI spillover measures. None of the interaction terms are well determined in column 2. Once we disaggregate by type of FDI spillover, joint venture and wholly foreign owned, we find that having a direct link with an upstream FDI firm, associated with a technology transfer, mitigates to a certain extent the negative indirect externality, associated with a dominance of wholly-foreign owned firms in upstream sectors. In particular, a one percentage point increase in the proportion of inputs supplied by wholly-foreign owned firms in upstream sectors is associated with a decline in productivity of 0.7 per cent for firms with no linkages. Firms with linkages that include technology transfers experience significantly less

of a decline in productivity equivalent to 0.2 per cent. A large part of the negative indirect spillover remains unexplained empirically and could be attributed to one of the many theoretical arguments put forward for the existence of negative FDI spillovers from a dominance of upstream FDI firms to downstream domestic sectors.

One hypothesis that fits well with our findings is that the negative indirect spillover from upstream FDI is due to FDI firms gaining a dominant market position in upstream sectors leading to less competition and generally higher priced inputs for domestic downstream producers. The negative effect is significantly reduced for domestic downstream producers which receive inputs directly from FDI firms and where these linkages are associated with direct transfers of technology. In contrast, we find very little evidence to suggest that spillovers from downstream FDI firms are due to direct linkages. One possible explanation is that in Vietnam foreign firms are most dominant in 'input' sectors where there are likely to be forward linkages. For example, as illustrated in Table 1, foreign firms dominate the equipment sectors which include computers and electronics, electrical equipment, transportation and other types of machinery, all sectors with forward linkage characteristics as per Hirschman (1958). Our findings suggest that firms directly linked with foreign firms in these sectors experience direct productivity spillovers through this link. FDI firms are much less dominant in downstream sectors that are more associated with the production of final goods, such as food products, wood and paper products and pharmaceuticals. This reduces the potential for backward spillovers through direct linkages (Hirschman, 1958).²¹

Overall, our results for indirect vertical spillovers from FDI are consistent with findings in other empirical studies of this kind. Our key point of departure is that we find evidence that domestic firms that are directly linked with upstream firms experience an additional positive productivity impact not captured by the indirect spillover measure. We also find some evidence that part of the negative indirect forward spillover is mitigated by positive direct spillovers through linkages. These findings support the Giroud et al. (2012) critique of the indirect spillover measure. Arguably, the standard sector-level measures used in the literature do not account for the effects of linkages or technology transfers that we capture here through the firm-specific measures.

5.3. Robustness checks

Table 9 presents findings from two robustness checks. In column 1 we highlight the core results from the main models presented in Tables 6–8. In column 2 we present results when we include controls for the sector-level concentration. The rationale for this robustness check is that we only have data on the value of inputs and outputs and so cannot estimate physical productivity. This implies that using our measure, productivity changes will embody both within-firm efficiency gains and changes in prices and/or mark-ups that cannot be easily disentangled. By focusing on the productivity effects in competitive sectors, where mark-ups are lower, we attenuate the possibility that the observed productivity effects are due to changes in mark-ups as opposed to real productivity improvements (Amiti and Konings, 2007). Our second stage empirical model is adapted to take account of sector-level concentration through the inclusion of interaction terms between the various measures of FDI spillovers and linkages and the HHI. The results presented in column 2 of Table 9 show the relationship between indirect/direct FDI spillovers and the productivity of firms in competitive sectors. In column 3 we report the findings when we estimate productivity using Olley and Pakes (1996) approach.

Our robustness tests confirm our core results. We find evidence for negative indirect forward spillovers in all cases. We also find that direct forward linkages are productivity enhancing. Evidence for positive indirect backward FDI spillovers from joint venture foreign-owned firms is also confirmed in all models. The interaction between direct forward linkages with technology transfers and indirect forward spillovers from wholly-foreign owned firms is positive and statistically significant when we control for concentration but is not well determined when we use the OP productivity measure. It is interesting to note that in no case are direct backward linkages well determined confirming our finding that direct spillovers through this channel appear to be non-existent.

6. Conclusion

In this paper we explored the impact of FDI on the productivity of domestic firms in Vietnam. The analysis specifically addressed whether foreign investment leads to productivity spillovers, and the extent to which these spillovers are due to direct linkages, real technology transfers or other indirect effects. Focus was on vertical linkages through the supply chain from upstream foreign-invested firms (supplying inputs to downstream domestic firms) and from downstream foreign-invested firms (purchasing inputs from domestic firms). We also considered whether spillovers from wholly foreign-owned firms are different to those from joint ventures.

²¹ Another possible explanation relates to the bargaining power of the domestic firm in the negotiation of the terms of the transaction with the foreign enterprises. Where the FDI firm is the customer and the domestic input supply sector is competitive, the foreign-owned customer is likely to have more bargaining power than the domestic firm and so technology transfers and other potential spillovers will be accounted for in the price the foreign firms negotiate for the inputs they buy. The bargaining power of the foreign-owned customers will be further strengthened where there are import substitutes available. In contrast, when the Vietnamese firm is the customer purchasing inputs from an FDI firm they arguably have more bargaining power and as domestic firms will have more information about the local market. As such they are in a better position to negotiate more favourable contract terms. This has the potential to lead to productivity gains (such as embodied technologies or support services, for example) over and above that which they pay for in the price of the inputs.

Table 9
Robustness checks.

Result	(1) Main model	(2) Controlling for HHI ^a	(3) Olley-Pakes
<i>Table 6: Indirect spillovers</i>			
Forward	−***	−***	−***
Forward JV	−*	−*	+(<i>p</i> =0.277)
Forward 100% for	−***	−***	−***
Backward	+**	+**	+(<i>p</i> =0.277)
Backward JV	+**	+**	+***
Backward 100% for	+(<i>p</i> =0.108)	+	−(<i>p</i> =0.525)
<i>Table 7 (column 3):</i>			
<i>Direct linkages</i>			
Forward linkage	+**	+**	+
Backward linkage	+(<i>p</i> =0.357)	+(<i>p</i> =0.366)	+(<i>p</i> =0.223)
<i>Indirect spillovers</i>			
Forward JV	−(<i>p</i> =0.109)	−(<i>p</i> =0.133)	+(<i>p</i> =0.410)
Forward 100% for	−***	−***	−***
Backward JV	+(<i>p</i> =0.156)	+(<i>p</i> =0.143)	+***
Backward 100% for	+	+	+(<i>p</i> =0.970)
<i>Interactions</i>			
For JV: Linkage × spillover	−(<i>p</i> =0.940)	−(<i>p</i> =0.843)	+(<i>p</i> =0.767)
For 100: Linkage × spillover	+(<i>p</i> =0.222)	+(<i>p</i> =0.247)	+(<i>p</i> =0.361)
Back JV: Linkage × spillover	+	+	+(<i>p</i> =0.376)
Back 100: Linkage × spillover	−(<i>p</i> =0.890)	−(<i>p</i> =0.887)	−(<i>p</i> =0.155)
<i>Table 8 (column 3)</i>			
<i>Direct linkages</i>			
Forward linkage with tech transfer	+(<i>p</i> =0.249)	+(<i>p</i> =0.270)	+(<i>p</i> =0.248)
Forward linkage no tech transfer	+	+	+
Backward linkage with tech transfer	+(<i>p</i> =0.832)	+(<i>p</i> =0.808)	+(<i>p</i> =0.717)
Backward linkage no tech transfer	+(<i>p</i> =0.321)	+(<i>p</i> =0.392)	+(<i>p</i> =0.212)
<i>Indirect spillovers</i>			
Forward JV	−(<i>p</i> =0.111)	−(<i>p</i> =0.158)	+(<i>p</i> =0.416)
Forward 100% for	−***	−***	−***
Backward JV	+(<i>p</i> =0.160)	+(<i>p</i> =0.163)	+***
Backward 100% for	+	+	+(<i>p</i> =0.962)
<i>Interactions</i>			
For JV: linkage with tech × spillover	−(<i>p</i> =0.401)	−(<i>p</i> =0.327)	−(<i>p</i> =0.392)
For JV: Linkage no tech × spillover	+(<i>p</i> =0.685)	+(<i>p</i> =0.757)	+(<i>p</i> =0.440)
For 100: Linkage with Tech × spillover	+	+	+(<i>p</i> =0.266)
For 100: Linkage no tech × spillover	+(<i>p</i> =0.757)	+(<i>p</i> =0.775)	+(<i>p</i> =0.356)
Back JV: Linkage with tech × spillover	+(<i>p</i> =0.623)	+(<i>p</i> =0.481)	+(<i>p</i> =0.741)
Back JV: Linkage no tech × spillover	+	+(<i>p</i> =0.108)	+(<i>p</i> =0.480)
Back 100: Linkage with tech × spillover	+(<i>p</i> =0.643)	+(<i>p</i> =0.569)	−(<i>p</i> =0.900)
Back 100: Linkage no tech × spillover	−(<i>p</i> =0.553)	−(<i>p</i> =0.766)	−*

^a By including interaction terms between each variable and the measure of sector-level concentration (HHI) we can isolate the impact of spillovers and linkages in competitive sectors. Any observed effects in competitive sectors are likely to be due to real productivity improvements rather than increases in mark-ups.

* *p* < 0.10.

** *p* < 0.05.

*** *p* < 0.01.

Our paper makes a novel contribution to the literature by disentangling direct spillovers through linkages from indirect spillover effects of FDI. Arrow (1969) highlights that knowledge diffusion often requires direct (inter-personal) interaction and that knowledge diffusion is not an automatic process. To arrive at a clearer picture of overall knowledge/technology transfers, research is therefore needed to understand better the respective mechanisms behind spillovers through direct linkages and indirect spillover effects of FDI. Arguably, treating these concepts separately in empirical studies may yield insights to better understand the heterogeneous country effects of FDI knowledge/technology transfers found in the literature.

Overall, our results suggest that spillovers are more likely through vertical than through horizontal spillovers. Consistent with other empirical findings we found evidence of (i) positive spillovers from downstream FDI firms, in particular joint venture FDI firms, to domestic input suppliers, and (ii) negative spillovers from upstream FDI firms to downstream domestic producers. More importantly, once we considered direct linkages between firms we found that domestic firms experience positive productivity spillovers through their direct linkages with upstream FDI suppliers of inputs. This effect is not captured by indirect spillover measures. Our results also suggest that the negative spillovers from wholly foreign-owned firms in upstream sectors are less for domestic firms directly linked with foreign input suppliers where these links are associated with technology transfers.

Our findings provide new evidence on the interaction between FDI and private domestic firms which can help inform the debate on the desirability of attracting FDI. The results of our investigation show that while there are indirect spillovers associated with FDI that provide benefits beyond those internalized through market transactions, a large part of the spillover from FDI, particularly forward spillovers, accrues to firms which are directly linked to FDI input suppliers. This implies that policies aimed at attracting FDI should be continued – but also that they should be coupled with supporting improved conditions for the direct transfer of knowledge between firms.

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Appendix A

See [Table A1](#).

Table A1
TCS sample disaggregated by manufacturing sectors (2-digit).

		(1) Full sample	(2) 2009	(3) 2010	(4) 2011	(5) 2012	(6) Private domestic total	(7) Private domestic with productivity estimate
10: Manufacture of food products	10 and 11 merged for productivity estimation	3553	852	925	919	857	2998	2148
11: Manufacture of beverages		375	91	96	100	88	289	190
13: Manufacture of textiles		998	253	243	264	238	640	490
14: Manufacture of wearing apparel		1813	455	451	481	426	1041	650
15: Manufacture of leather and related products		429	159	161	58	51	213	150
16: Manufacture of wood and products of wood and cork		1656	394	419	441	402	1528	1148
17: Manufacture of paper and paper products		1303	319	329	341	314	1101	793
18: Printing and reproduction of recorded media		564	139	149	147	129	423	270
20: Manufacture of chemicals and chemical products	20 and 21 merged for productivity estimation	1009	247	254	258	250	592	424
21: Manufacture of pharmaceuticals, medicinal chemical and botanical products		259	65	64	67	63	137	90
22: Manufacture of rubber and plastics products		2183	562	542	558	521	1345	958
23: Manufacture of other non-metallic mineral products		2550	607	640	679	624	2280	1556
24: Manufacture of basic metals	24 and 25 merged for productivity estimation	676	163	167	183	163	570	376
25: Manufacture of fabricated metal products, except machinery and equipment		2575	627	658	673	617	1911	1304
26: Manufacture of computer, electronic and optical products	27, 28 and 29 merged for productivity estimation	269	69	72	67	61	100	55
27: Manufacture of electrical equipment		573	135	147	148	143	308	198
28: Manufacture of machinery and equipment n.e.c.		584	150	146	153	135	468	318
29: Manufacture of motor vehicles, trailers and semi-trailers	29, 30 and 32 merged for productivity estimation	221	44	56	63	58	89	55
30: Manufacture of other transport equipment		513	146	132	134	101	313	205
32: Other manufacturing		538	142	138	135	123	171	106
31: Manufacture of furniture		1744	389	433	483	439	1339	963

Note: Sector 12, Manufacture of tobacco products and sector 19, manufacture of coke and refined petroleum products are excluded due to the very small number of firms operating in this sector in Vietnam.

Appendix B. Supporting information

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.euroecorev.2015.02.005>.

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