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Measuring the Interdependence of Multinational Firms' Foreign Investments

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Abstract: Earlier work found evidence for geographic linkages of aggregate foreign direct investment (FDI) across countries and country-pairs. From a theoretical point of view, such linkages at the macroeconomic level may root in between-firm as well as within-firm linkages and originate from information spillovers across or within firms in exploring unknown markets, and vertical linkages between production plants across different locations within the firm. We use data on the universe of German multinational enterprises (MNEs) to empirically explore how marginal investments at one foreign affiliate depend on investments at other affiliates *within* the same MNE. The empirical approach employs two *channels* or *modes* of cross-affiliate interdependence: mere geography (capturing *horizontal linkages* through correlated learning and horizontal competition within the firm) and input-output relationships within or across industries (which capture *vertical linkages*). Adding to earlier findings at the aggregate level, we find evidence of a significant interdependence of investments within the firm. In the firm-level data at hand, vertical linkages appear to be more important than horizontal ones. Investments at one location tend to stimulate investments at other locations of the same MNE, particularly if input linkages are strong. The opposite seems to be true for output linkages. Beyond vertical linkages, mere geographic proximity matters only to a minor extent. This suggests that evidence of linkages through geographic closeness at aggregate data levels accrue mainly to reasons of vertical linkages within networks of affiliates.

Key words: Multinational firms; Foreign affiliates; Foreign direct investment; Spatial econometrics; Interdependence; Horizontal vs. vertical linkages; Firm-level analysis
JEL codes: C31; D22; F21; F23; F68; G31; H32

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1 Introduction

In general equilibrium and under resource constraints at the level of countries, aggregate bilateral foreign investments and foreign affiliate sales are known to be interdependent across host countries for a given parent economy (Baltagi, Egger, Pfaffermayr, 2008; Blonigen, Davies, Waddel, and Naughton, 2007) as well as across parent countries for investments in a given host economy (Blonigen, Davies, Naughton, and Waddel, 2008). Such interdependence leads to the transmission of country-specific shocks in the world investment system, whereby (geographically) more adjacent countries are stronger recipients as well as transmitters of shocks. All existing evidence on interdependent foreign investments, however, seems to pertain to aggregate investment flows or stocks. While such aggregate analysis is useful to understand the relevance of interdependence at the level of countries, theoretical models used to motivate empirical studies of interdependence mainly rely on effects between firms.

This paper contributes to the empirical literature measuring interdependence of foreign direct investment (FDI) with a particular focus on whether such interdependence arises *across* affiliates *within* MNEs. To measure whether investment of one particular entity of an MNE depends on investments carried out by other entities of the same MNE, we discern different channels of interdependence such as input-output relationships or mere geographic proximity. This approach relates our paper to a recent literature on the organization of production along the value chain (e.g., Antràs and Chor, 2013; Costinot, Vogel, and Wang, 2013), since using weights on input-output dependence allows us to draw conclusions about the relative position (upstream or downstream) of entities (and countries) in the global value chain. Moreover, the approach is related to the literature unveiling vertical international linkages in the productivity (see Bernstein and Mohnen, 1997; Morrison Paul and Siegel, 1999; Keller, 2002; Smarzynska Javorcik, 2004), growth and volatility (Burstein, Kurz, and Tesar, 2008; Kleinert, Martin, and Toubal, 2012; Oberhofer and Pfaffermayr, 2013), and, hence, the profitability across units (firms, sectors, and even countries). Comparing input-output-related interdependencies of affiliates' investments to geographic-distance-related interdependencies also permits drawing conclusions about the relative importance of different channels of interdependence. Finally, while there is a large literature on productivity spillovers from FDI on domestic firms or generally across firms, we add to this literature by providing evidence on interdependencies that occur within a firm, but across affiliates and countries.

Our analysis is probably most closely related to the study by Chen (2011). The paper by Chen (2011) is based on subsidiary-level data and suggests horizontal as well as vertical interdependence in the location of subsidiaries of MNEs. While the focus of our study is on the relative importance of different channels (horizontal or vertical linkages) through which investment at a given location is affected by marginal investment decisions at other locations, the paper by Chen (2011) examines the effect of existing production networks on the location of foreign production. That is, Chen (2011) analyzes how horizontal or vertical linkages determine the *extensive* margin of foreign investment. In contrast, our analysis of interdependencies in the *intensive* margin of investment is conditional on network location. While our focus is on the intensive margin of investment, we explore the relative importance of adjustments at the intensive margin (changes in investment by old affiliates) vs. adjustments at the extensive margin (investment by new affiliates).

Our empirical analysis utilizes census-type panel data of all German MNE parents and their foreign affiliates provided by Deutsche Bundesbank. One obvious advantage of this data-set is that it allows us to control for affiliate- and firm-specific characteristics, whose omission in country-level studies might lead to aggregation bias. Moreover, the availability of a large number of firm-affiliate-host-country-year data points permits identification at relatively great precision in comparison to country-pair-time aggregated data. Also, the census-type data at the firm and affiliate level help avoiding a bias associated with missing data points, which affects virtually all attempts to analyze interdependence at the aggregate foreign investment level from incomplete (e.g., survey-based or otherwise selected) data-sets.[1] The same, of course, is true for most firm-level data-sets, which cannot provide a similarly complete picture as our data-set can.[2] Given that group effects are at the heart of our analysis, the latter points are particularly important.

We model the stock of foreign direct investment (FDI) invested in a foreign entity as to depend on a weighted function of FDI stock elsewhere within the firm.[3] Our estimation strategy does not condition on the total amount of FDI invested in all units of a firm – by focusing on its allocation only – but it allows aggregate investments to vary. Thus, we do not view investments to be necessarily substitutive across locations but allow them

[1]Notice that, unlike with trade, only few countries provide exhaustive data-sets on their FDI. With interdependent observations, omitting some countries or country-pairs from the data leads to measurement error of the regressors and an associated inconsistency of the parameters determining aggregate country-level or country-pair-level FDI.

[2]Again, much more so than with firm-level exports, only few countries provide exhaustive data-sets on their MNEs and the associated affiliates and foreign direct investments. With interdependent observations, omitting some affiliates from the data leads to measurement error of the regressors and an associated inconsistency of the parameters determining investment at the level of affiliates and firms.

[3]We use the foreign affiliate's stock of fixed and intangible assets attributable to the parent company as a measure of FDI related to production activities.

to be substitutive or complementary. For estimation and identification of interdependence effects we specify a spatial autoregressive (SAR) model which allows for fixed effects at the level of foreign affiliates. A novel feature of our analysis is that the structure of interdependence is affiliate-firm-specific to account for differences in MNEs' vertical and geographical (horizontal) organization of production. Moreover, using different weights to distinguish between investments that are relatively more downstream vs. upstream vs. geographically proximate enables us to provide the following novel insights about the interdependence of investment within firms: (i) what is the relative importance of geographical proximity vs. input-output linkages as channels through which interdependencies in investment occur and, (ii) what is the relative importance of the upstream vs. downstream channel.

The main findings of our analysis can be summarized as follows. First, vertical (input-output) relations between affiliates seem to play a greater role in explaining interdependence than horizontal ones (mere geography). However, conditional on input-output relationships, investment of a given entity declines with bigger proximate investments at other entities of the same MNE. Second, while investments in vertical input-related affiliates exert a complementary impact on investment in a given affiliate (positive interdependence), the opposite is true for investments at vertical output-related affiliates. In other words, input-linked upstream investments of affiliates within an MNE's affiliate network stimulate investments in more downstream affiliates, while output-linked downstream investments of affiliates reduce investments in more upstream affiliates. Hence, vertical interdependence is asymmetric between upstream and downstream relationships. Third, while vertical interdependence seems to be driven by adjustments at the extensive margin (investment at other locations by new affiliates), horizontal interdependence seems to be driven by the intensive margin adjustments (changes in investment by old affiliates). Fourth, the relative sensitivity to shocks varies to a relatively large degree across firms (depending on the location and size of their affiliate network) and across host countries (depending on the vertical and horizontal size and structure of the hosted affiliate network).

The finding that more horizontal investments in proximate countries lead to less investments at a given affiliate, conditional on input-output relations, is consistent with the use of foreign affiliates as export platforms (see Ekholm, Forslid, and Markusen, 2007; Tintelnot, 2017). Our results regarding vertical linkages are consistent with findings of the literature on spillover effects. Smarzynska Javorcik (2004) finds evidence that positive (productivity) spillovers from foreign affiliates to domestic firms mainly occur through backward linkages (through the intermediate input channel), but not through forward linkages. We find a similar pattern for a given foreign entity which is linked through the *input channel* to upstream entities anywhere within the same MNE. Our results also suggest a U-shaped pattern of investment along the value chain, similar to the one found in the context of the evolution of countries and industries (see Shin, Kraemer, and Dedrick, 2012, for an empirical application in the global electronics industry). This suggests that the profitability is particularly high at the root or origin of the production process or product cycle (where research intensity is high) and also at the end of it (where input costs are low and the service intensity is high). In our setting, with Germany as the parent country, we would expect that processes with high research intensity in the first part of the curve are mainly located in the parent country (from where positive technology spillovers are transmitted elsewhere). Since Germany is a mature economy, we expect investments to be gradually shifted to other countries with greater growth potential and profits. According to our empirical estimates, for a given foreign affiliate, investments of input suppliers are positively related to a recipient affiliate's own investments, while investments of entities to which output is forwarded are negatively related to an affiliate's own investments. This suggests that investments are shifted downstream towards the end of the production line along the right part of the U-shaped curve.

We may also interpret our results in light of the recent literature on the organization of global value chains. In particular, Alfaro, Antràs, Chor and Conconi (2015) suggest that upstream or downstream integration choices depend on the relative size of the elasticity of demand for a firm's final product and the elasticity of substitution across sequential inputs. If inputs are not particularly easy to substitute, investments across vertically linked units are found to be positively correlated, in which it is optimal for the firm to integrate only the most downstream stages. This is consistent with our finding of a positive relationship between investment of a given affiliate and investments of all other affiliates within the MNE if the affiliate is linked through the input channel. Moreover, while we cannot model the outsourcing decision, the findings in Alfaro et al. (2015) would suggest that the integrated part of the total value chain for the input-linked affiliates in our data tends to be more downstream. If instead inputs are easy to substitute, investments at different stages are negatively correlated and Alfaro et al. (2015) suggest that a firm finds it optimal to integrate relatively upstream stages. The negative interdependence found for affiliates linked through the output channel is in line with the assumption that the inputs supplied by these affiliates are characterized by a high substitutability, suggesting that the integrated part of the value chain we observe in our data for the output-linked affiliates is more up the stream. All this suggests that both goods produced and relationship-specific investments made along the value chain become more specialized and less substitutable, which is again in line with the aforementioned U-shaped curve pattern.

The proposed empirical approach allows us to carry out a number of interesting experiments. For example, we may gauge the relevance of an asset reallocation across existing affiliates in response to location-specific shocks. We are also able to assess the importance of different channels of interdependence depending on location. This includes an identification of particularly shock-prone locations from the viewpoint of German investors (which account for a significant share of world FDI). On average and conditional on a shock of the same size across all existing affiliates there, the United States, China and Brazil are the most important sources of investment shocks (spillovers) to German affiliates elsewhere. The German affiliates in Botswana, Madagascar, Iceland and Lebanon are the most important recipients of investment shocks from German affiliates elsewhere. This shows that intra-firm effects on investment are asymmetric with regard to their impact on units up the stream versus down the stream. The general strength of interdependence among the affiliates in an MNE and its qualitative impact depend on the (vertical and horizontal) structure of an MNE's affiliate network.

Our findings also have policy implications. Most obviously, the degree to which a country is exposed to shocks transmitted from other countries depends on the structure of foreign direct investment in such a country. Moreover, the results imply that the interdependence of affiliate-level investment decisions does not permit treating affiliates as independent within the firm in empirical work without encountering biased and inconsistent estimates of parameters and comparative static effects. This is relevant for the analysis of policy effects such as the ones of national or international tax policy, as responses to national and international tax incentives have consequences on investments not only within but also across national borders. Our analysis at the affiliate level suggests that cross-border effects go beyond the (mechanical) interdependence emerging and considered in structural general equilibrium models of multinational firms.

The remainder of the paper is organized as follows. Section 2 outlines the main theoretical reasons for investment interrelatedness and how our paper relates to this literature. Section 3 describes the empirical approach as well as the interdependence or linkage measures used. Section 4 describes the data-set used in the present analysis, before Section 5 presents the findings. Section 6 states a brief conclusion.

2 Reasons for contagious investments and related literature

We may distinguish between three different explanations for interdependence of foreign investments within firms but across affiliates and countries: (i) vertical input-output linkages within MNEs; (ii) internal capital markets of MNEs; (iii) correlated learning over sequential investments of MNEs. Point (i) suggests that single entities of the MNE are part of a global value chain and intermediate goods are used by different affiliates at different production stages within and across different countries. Bernard, Jensen, Redding, and Schott (2010) show that such production leads to tangible assets trade within an MNE. More recently, Atalay, Hortaçsu, and Syverson (2014) have argued that intra-firm transfers along vertical production lines are often associated with intangible assets. Intra-firm trade of intangible inputs may include transfers related to the simultaneous use of technology and knowledge (McGrattan and Prescott, 2009) across locations and entities, which does not necessarily require vertical goods linkages but is also relevant in the context of horizontal FDI (see Markusen's, 2002, knowledge capital model of the multinational firm for theoretical arguments along those lines; see Carr, Markusen, and Maskus, 2001, and Markusen and Maskus, 2002, for aggregate evidence on vertical versus horizontal MNE activity decisions). Alfaro et al. (2015) analyze outsourcing decisions along the value chain. They argue that organizational decisions at a given stage of the value chain affect all stages of the value chain, because the incentives to make relationship-specific investments depend on investments made by upstream suppliers. Depending on the relative size of the elasticity of demand for the final good and the elasticity of substitution across sequential inputs, investments at different production stages are found to be positively or negatively correlated to each other.

Point (ii) argues that entities of MNEs are linked through an internal capital market. Egger, Keuschnigg, Merlo, and Wamser (2014) demonstrate that MNEs may and do use this market to allocate scarce funds. In particular, funds are channeled to those affiliates with the highest excess return on investment. Differences in this excess return are driven by capital market frictions, differences in productivity, taxes, and local institutions. Since the allocation of funds involves lending and borrowing relationships between affiliates, the existence of internal capital markets provides for a natural reason of why there is interdependence across all – vertical and horizontal – entities of an MNE.

Point (iii) recognizes that investments might be connected through complementarities at the extensive margin. Egger, Fahn, Merlo, and Wamser (2013) show that *correlated learning* causes interdependence since information gathered at one location by one affiliate can be used to learn about conditions in other, particularly similar countries.[4]

[4]While the sequencing of foreign investments determines the direction of learning, this is out of the scope of the present study, as it focuses on the interdependence of investments at the intensive affiliate margin, i.e., at a given size and location of the affiliate network, at each point in time.

All of this suggests that an empirical approach modeling investment at a given affiliate needs to consider the interdependence of such investments across all affiliates within a firm.[5] Moreover, the extent of interdependencies may vary between firms as well as affiliates. A natural approach to model the extent of interdependence is geographical distance. For instance, Keller and Yeaple (2013) argue that tangible and intangible transfers from headquarters to affiliates decline with distance from their headquarters. Another measure to capture the degree of interdependence – or the closeness of affiliates – is to model input-output relations between entities. Depending on a firm's specialization, input-output relations determine whether a firm is closer to the core of activities or not, and whether it is further up or down the stream or not, with potential consequences for the prioritization of its investment plans. The relative importance of *horizontal linkages* through geography among units in the same sector and of *vertical linkages* through input-output (or upstream and downstream) relationships among units in different sectors at the level of affiliates is not known.

More formally, we could think of profitability of a foreign investment in affiliate i at some time t, Π_{it}, to be a function of stocks of assets at all affiliates of the same firm, $(FDI_{1t}, ..., FDI_{N_f t})$, where N_f is the number of all affiliates of firm f to which i belongs. Assume that new investments at location i and time t are proportional to their profitability, whereby $\partial FDI_{it}/\partial FDI_{jt} \propto \partial\Pi_{it}/\partial FDI_{jt}$. Moreover, let us parameterize the latter as $\partial FDI_{it}/\partial FDI_{jt} = \mathbf{w}_{ijt}\boldsymbol{\delta}$, where $\mathbf{w}_{ijt}$ is a row vector reflecting channels of influence of investment at j on i (such as input-output channels, horizontal competition and cross-effects on sales, etc.) and $\boldsymbol{\delta}$ is a conformable column vector of importance weights. The overall level of foreign assets at j and t then induces an overall partial impact on FDI_{it} of $\mathbf{w}_{ijt}\boldsymbol{\delta}FDI_{jt}$. All other (non-$i$) affiliates together would have a joint partial impact on FDI_{it} of $\overline{FDI}_{it} \equiv \sum_{j \neq i \in \mathcal{N}_{ft}} \mathbf{w}_{ijt}\boldsymbol{\delta}FDI_{jt}$, where the summation is over affiliates in the same firm f, $\mathcal{N}_{ft}$.

3 Empirical approach

This paper considers several channels of interdependence determining individual firms' (intensive) marginal FDIs: one related to mere geography (horizontal proximity) and other ones related to input-output relationships (vertical proximity) between foreign affiliates.

[5]On a broader scale, the focus on horizontal versus vertical interdependencies of the present paper relates it to the literature on affiliate networks (see Egger, Fahn, Merlo, and Wamser, 2013; Oberhofer and Pfaffermayr, 2003) and to the recent literature on the value chains and the organization of firms (e.g., Antràs and Chor, 2013).

3.1 Econometric model

Let us use indices f, i, and j to refer to the ith or jth foreign affiliate of firm f. Altogether, there are F firms, and the fth firm has N_f foreign affiliates during the sample period. Since firms enter and exit (and so do affiliates), the number of firms in year $t \in \{1 \ldots, T\}$ is $F_t \leq F$ and the number of firm f's affiliates in year t is $N_{ft} \leq N_f$. Let us denote the set (as opposed to the number) of foreign affiliates in year t and all years as $\mathcal{N}_{ft}$ and $\mathcal{N}_f = \mathcal{N}_{f1} \cup \ldots \cup \mathcal{N}_{fT}$. In year t, the stock of FDI of firm f's affiliate i is determined as

$$FDI_{it} = Z_{it}\delta + u_{it}, \quad Z_{it} = [\overline{FDI}_{it}^{D}, (\overline{FDI}_{it}^{s}), X_{it}], \quad \delta = [\lambda^D, (\lambda^s), \beta], \quad (1)$$

where X_{it} captures exogenous determinants of FDI. Notice that we put parentheses around $\overline{FDI}_{it}^{s}$ and λ^s in equation (1). This is to indicate that more than one concept of s may be considered at a time (e.g., input and output relationships may enter separately). We usually refer to $\overline{FDI}_{it}^{D}$ and $\overline{FDI}_{it}^{s}$ as interdependence or linkage terms of FDI_{it}, and they are defined as

$$\overline{FDI}_{it}^{\ell} = \sum_{i,j \in \mathcal{N}_{ft}} w_{ijt}^{\ell} FDI_{jt}, \quad \ell \in \{D, s\}. \quad (2)$$

The parameters w_{ijt}^{ℓ} in equation (2) are referred to as *linkage weights* in the literature, and they aggregate other affiliates investments within a firm and year according to the distance metric indexed by D and the input-output metric indexed by s. They are normalized by a scalar as suggested by Kelejian and Prucha (2010) as

$$w_{ijt}^{\ell} = \frac{w_{ijt}^{\ell 0}}{max \sum_{i,j \in \mathcal{N}_{ft}} w_{ijt}^{\ell 0}}, \quad w_{ijt}^{\ell 0} \geq 0, \quad (3)$$

where $w_{ijt}^{\ell 0}$ is the unnormalized counterpart to w_{ijt}^{ℓ},[6] having the property of $w_{ijt}^{\ell} = 0$ for all units $j = i$.

3.2 Channels of interdependence (weights $w_{ijt}^{\ell 0}$)

The channels of interdependence, or weighting schemes, considered in this paper are based on geographical distance ($\ell = D$) and sectoral, vertical proximity ($\ell = s$). While the former is measured by the great circle distance between the countries two affiliates are based in, the latter is based on measures of the intensity of input-output relations consistent with the German input-output table.

[6] Unlike row-normalized weights, the suggested ones bear the advantage of preserving the notion of *absolute proximity* in the ℓth metric.

3.2.1 Inverse geographical distance weights (w_{ijt}^{D0})

We define inverse geographical distance weights as

$$w_{ijt}^{D0} = d_{ij}^{-1} \quad \forall\, i \in \mathcal{N}_{ft},\ j \in \mathcal{N}_{ft}, \tag{4}$$

where d_{ij}^{-1} denotes either the great circle distance between the main cities of the (different) countries affiliates i and j locate in, or the average internal distance of the (same) country i and j locate in.[7] If the condition in (4) is not met, i.e., if we cross the boundaries of an MNE, $w_{ijt}^{D0} = 0$.

In robustness tests, we assume alternative decay functions for the inverse distance. For this, we specify d_{ij}^{-1} as $(d_{ij}^{-1})^2$ and $(d_{ij}^{-1})^{0.5}$. The reasoning behind these additional tests is that $(d_{ij}^{-1})^2$ puts relatively less weight on distant (more weight on close-by) affiliates than in the benchmark with $(d_{ij}^{-1})^1$. And $(d_{ij}^{-1})^{0.5}$ puts relatively more weight on distant (less weight on close-by) affiliates compared to the benchmark (see Bode, Nunnenkamp, and Waldkirch, 2012; Baltagi, Egger, and Pfaffermayr, 2007). In an additional robustness test of the measure of distance within countries, we give all affiliates within a country the same weight across countries. Specifically, we set $w_{ijt}^{D0} = d_{ij}^{-1} = 1$ whenever affiliates i and j are located in the same country (implicitly assuming that intra-national distance plays no role).

3.2.2 Input-output weights (w_{ijt}^{s0})

The second type of interdependence measure, w_{ijt}^{s0}, reflects the amount of intermediate inputs and/or outputs which the sectors of affiliates i and j typically exchange with each other by German standards.[8] The elements w_{ijt}^{I0}, w_{ijt}^{O0}, w_{ijt}^{IO0} measure the amount of inputs, outputs, and inputs plus outputs, respectively, the sector of i typically uses from/provides to the sector of j. Notice that w_{ijt}^{s0} is time-variant for two reasons: first, the intensity of input-output relationships changes over time; second, the sectors in which i and j mainly operate in might change over time.[9] More precisely, denote the German input-output matrix spanned by the units of firm f in year t as $\boldsymbol{\Omega}_{ft}$ and its $(ij)^{th}$ element as ω_{ijt}. In this case, ω_{ijt} measures the input of the sector of unit j from the one of unit i at time t. The three

[7]The great circle distance is calculated using the haversine formula. The internal distance measure and the coordinates of the main cities are taken from CEPII's GeoDist database (See Mayer and Zignago, 2011, for a description).

[8]It appears plausible to assume that the covered MNEs use German technology standards in their affiliate network. Using a best-practice technology throughout the affiliate network entails one of the major advantages of MNEs relative to stand-alone firms.

[9]Moreover, w_{ijt}^{s} and w_{ijt}^{D} vary only across ijt.

measures of sectoral interdependence are defined as

$$w_{ijt}^{I0} = \omega_{ijt} \quad \forall\, i \in \mathcal{N}_{ft},\ j \in \mathcal{N}_{ft}, \tag{5}$$
$$w_{ijt}^{O0} = \omega_{jit} \quad \forall\, i \in \mathcal{N}_{ft},\ j \in \mathcal{N}_{ft}, \tag{6}$$
$$w_{ijt}^{IO} = \omega_{ijt} + \omega_{jit} \quad \forall\, i \in \mathcal{N}_{ft},\ j \in \mathcal{N}_{f't},\ \mathcal{N}_{ft} = \mathcal{N}_{f't}. \tag{7}$$

If the conditions in (5) are not met, i.e., if we cross the boundaries of an MNE, w_{ijt}^{I0}, w_{ijt}^{O0}, and w_{ijt}^{IO} are zero.

3.2.3 The model specification in matrix notation

For our approach towards intra-firm investment interdependencies, it is important to note that the weighting schemes focus on interdependencies of affiliates i and j within parent firm f in a given year t. Therefore, the typical weights matrix for firm f at time t has size $N_{ft} \times N_{ft}$ and is defined as

$$\mathbf{W}_{ft}^{\ell} = [w_{ijt}^{\ell}] \quad \forall\, i, j \in \mathcal{N}_{ft}, \tag{8}$$

which has zero diagonal elements for all $\ell = \{D, s\}$. Stacking the data for all firms f in year t, we obtain a block-diagonal $N_t \times N_t$ matrix of the form

$$\mathbf{W}_t^{\ell} = diag(\mathbf{W}_{ft}^{\ell}). \tag{9}$$

Thus, using $\mathbf{FDI}_t = (FDI_{fit})$, $\overline{\mathbf{FDI}_t}^{\ell} = \mathbf{W}_t^{\ell}\mathbf{FDI}_t = (\overline{FDI}_{it}^{\ell})$, and $\mathbf{X}_t = (X_{it})$ to denote the corresponding stacked vector of elements across all firms, we may write the model for year t as

$$\mathbf{FDI}_t = \lambda^D \overline{\mathbf{FDI}_t}^{D} + (\lambda^s \overline{\mathbf{FDI}_t}^{s}) + \mathbf{X}_t \boldsymbol{\beta} + \mathbf{u}_t, \tag{10}$$

where $\mathbf{FDI}_t$, and $\mathbf{u}_t$ are $N_t \times 1$ vectors, $\mathbf{X}_t$ is a matrix of dimension $N_t \times k$ and $\boldsymbol{\beta}$ is a $k \times 1$ vector.[10] Again, we indicate by parentheses in (10) that more than one s-related interdependence term may be present at a time. In general, the interdependence terms $\overline{\mathbf{FDI}_t}^{\ell}$ are endogenous. However, the structure of interdependence of the model delivers valid instruments. This becomes clear by writing the reduced form of the deterministic part of the model,

$$\mathrm{E}(\mathbf{FDI}_t) = (\mathbf{I} - \lambda^D \mathbf{W}_t^D - (\lambda^s \mathbf{W}_t^s))^{-1} \mathbf{X}_t \boldsymbol{\beta}, \tag{11}$$

where several matrices $\lambda^s \mathbf{W}_t^s$ may enter additively the parentheses of the inverse in (11). A Taylor-series expansion together with the properties of $\mathbf{W}^{\ell}$ suggests that $(\mathbf{I} - \lambda^D \mathbf{W}_t^D - \lambda^s \mathbf{W}_t^s)^{-1} \mathbf{X}_t$ can be approximated well by a polynomial function so that $\overline{\mathbf{FDI}}^{D}$ and $\overline{\mathbf{FDI}}^{s}$ can be instrumented

[10] Note that our estimation approach will also allow for unobserved affiliate heterogeneity (see below).

well by $\overline{\mathbf{X}^D} = \mathbf{W}^D\mathbf{X}$, $\overline{\mathbf{X}^s} = \mathbf{W}^s\mathbf{X}$, $\overline{\mathbf{X}}^{Ds} = \mathbf{W}^D\mathbf{W}^s\mathbf{X}$, $\overline{\overline{\mathbf{X}}}^D = \mathbf{W}^D\overline{\mathbf{X}}^D$, $\overline{\overline{\mathbf{X}}}^s = W^s\overline{\mathbf{X}^s}$, etc., where it is sufficient in practice to use up to four powers (see Kelejian, Prucha, and Yuzefovich, 2004). We estimate a two-stage least-squares model with affiliate fixed effects (FE2SLS).[11]

3.2.4 Some general remarks on interdependence

The parameters on the variables $\overline{FDI}_{it}^{\ell}$ with $\ell \in \{D, I, O, IO\}$ should be interpreted in the following way. A positive effect of $\overline{FDI}_{it}^{D}$ means that, conditional on other determinants of foreign direct investment of firm f in affiliate i at time t, an increase in investments in closer affiliates within the same firm (i.e., ones with a bigger inverse distance) stimulates investment at the margin in affiliate i at time t. The latter we dub horizontal complementarity at the intensive foreign investment margin within the firm. A negative effect of $\overline{FDI}_{it}^{D}$ means the opposite, pointing to a substitutive relationship among investments at the intensive margin.

A positive effect of $\overline{FDI}_{it}^{s}$ implies that positive interdependencies are associated with the interdependence in terms of s within a parent's affiliates network. For instance, we might interpret a positive (negative) effect of $\overline{FDI}_{it}^{I}$ on FDI_{it} as evidence of an upstream vertical complementarity (substitution) in investments. Similarly, we might interpret a positive (negative) effect of $\overline{FDI}_{it}^{O}$ on FDI_{it} as evidence of a downstream vertical complementarity (substitution) in investments. A positive (negative) effect of $\overline{FDI}_{it}^{IO}$ on FDI_{it} could then be dubbed evidence of a general vertical complementarity (substitution) in investments. One consequence of a greater such interdependence is the greater vulnerability of affiliate networks in terms of shocks within the network. Whether shocks travel at all, primarily, or more strongly through mere geographic or input-output linkages is a question that only the data can answer.

[11] Badinger and Egger (2011) and Kelejian (2013) show that FE2SLS provides consistent estimates of λ^{ℓ} and $\boldsymbol{\beta}$ under a broad spectrum of assumptions. As shown above, the estimator we employ suggests using the weighted exogenous variables to instrument for the endogenous spatial lag. There might be a concern about the exclusion restrictions in the context of weighted variables measured at the level of the firm. We will address this by using as instruments lagged weighted characteristics of other affiliates in the same country and year that are not related to i and belong to another multinational firm. We are not concerned that these affiliates may be affected by the same (exogenous) shocks as i. What is important is that neither affiliate i nor the firm controlling i may directly affect the characteristics of other firms in period $t-1$. In particular, the latter should be the case as outcome of affiliate i is measured in period t, and the instruments are measured in period $t-1$.

4 Data and descriptive statistics

4.1 Data on the dependent variable

The main source underlying our data is the Microdatabase Direct Investment ($MiDi$) collected and provided by the German Central Bank (Deutsche Bundesbank). The database represents an annual unbalanced panel with German parent firms' individual affiliates as the unit of observation. The data capture the universe of German MNEs as it is a legal requirement for firms (and even private households) to report FDI above a threshold of €3 million in their balance sheet and if the participation is at least 10%. Indirect participating interests have to be reported whenever foreign affiliates hold 10% (50% as of 2007) or more of the shares or voting rights in other foreign enterprises with a balance sheet total in excess of €3 million.[12] For our approach we use the entire panel for the years 1997 to 2009. The dependent variable in our approach are the fixed (and intangible) assets of affiliate i attributable to parent f in year t in logs, FDI_{it}, as available from $MiDi$ and reported in million Euros.

4.2 Data underlying the channels of interdependence

Data on latitudes (lat_i), longitudes (lon_i), and geographical area ($area_i$) underlying the geographic weighting scheme, w^D_{ijt}, are taken from CEPII's GeoDist database.[13] The data underlying the input-output weighting schemes are taken from annual input-output tables for the German economy over the period 1997-2007, which are publicly available from the German Federal Statistical Office. Since input-output tables as of 2008 are not comparable to the previous ones[14], we use the one for 2007 for those two years. The time variance in input-output shares is minor so that this procedure seems justifiable. The calculation of inputs and outputs by the German Federal Statistical Office is based on the concept of a homogeneous production unit, which is closer to an affiliate (or a production plant) than a firm. The input, output, and input-output matrices are of size $sector \times sector$ with altogether 71 sectors of primary (raw material), secondary (manufacturing), and tertiary (services) type of the German economy, based on the so-called CAP classification. We aggregated this format to a 60×60 table to match it onto the foreign affiliate statistics as provided by Deutsche Bundesbank,

[12] The collection of annual statistics is stipulated by law through the Außenwirtschaftsgesetz (AWG) (Foreign Trade and Payments Act). The reporting requirements refer to Sections 56a and 58a of the AWG.They were enacted in 2002, but are applied consistently for all years of the panel. For a detailed description of the $MiDi$ database, see Lipponer (2011).

[13] See Mayer and Zignago (2011) for a description.

[14] See Statistisches Bundesamt (2014), p.4.

based on the NACE industry classification (see Table 4 in the Appendix for details). The columns of the input-output matrix represent the value of inputs used in a production sector in million Euros, and its rows represent the value of output of intermediate goods (or services) produced in million Euros.[15] Hence, both a bigger number of w_{ijt}^{D} and of w_{ijt}^{s} indicates greater proximity between two affiliates i and j at time t.

4.3 Data on explanatory variables

The vector $\mathbf{X}_{it}$ in equation (1) contains firm-time-specific as well as country-time-specific determinants of investment of MNE f at affiliate i and time t. We employ the following affiliate-time-specific variables from the *MiDi* database. First, $Sales_{it-1}$ and $Employees_{it-1}$ capture general lagged characteristics of foreign entities affecting investments in t. The former reflects affiliate-specific market size (demand) in logs and the latter an affiliate's supply capacity in terms of employment, also in logs. Second, we include $Competition_{it-1}$, the number of German competitors in the same sector and country as of the previous year. We calculate this variable by counting all affiliates $j \neq i$ in a country and year $t-1$ by sector. Among the country-time-specific explanatory variables, we include the following. First, we account for the $Corporate\ Income\ Tax_{it}$. Higher corporate taxes require a higher rate of return on investment and, hence, we expect this variable to be negatively related to affiliates' investments. Information on the statutory corporate tax rates is gathered from databases provided by the International Bureau of Fiscal Documentation (IBFD) and annual tax guides issued by Ernst&Young, PwC, and KPMG. Moreover, we include $Financial\ Freedom_{it}$, as published in the Heritage Indicators Database, which measures the banking efficiency as well as the independence of the financial sector from government control. At the extremes, a value of 100 indicates *negligible government interference*, whereas a value of 0 indicates *repressive government interference*. A greater financial freedom is associated with better access to the local capital market and lower costs of external financing. We expect this variable to be positively related to affiliate i's investments. Also, we employ the local inflation rate $Inflation_{it}$ from the International Monetary Funds' World Economic Outlook, which reflects aspects of the macro environment affiliate i is operating in. Finally, we include $Capital - Labor\ Ratio_{it}$, reflecting relative factor endowments in affiliate i's market in year t in logs, and GDP_{it}, the log of real GDP at constant U.S. dollars of the year 2000, as a measure for the size of a market at time t. The latter two explanatory variables are taken from the World

[15]The tables include domestic and imported intermediates used in production. Intermediates are valued at prices which exclude any taxes but include subsidies (see Kuhn, 2010, p.15).

Bank's World Development Indicator Database, where capital-labor ratios are calculated using the perpetual inventory method to estimate capital stocks.[16]

4.4 Descriptive statistics

Our analysis is based on a sample of 21,598 foreign affiliates of 6,059 German MNEs over the period from 1997-2009, resulting in an unbalanced panel with 134,781 observations.[17] The German affiliates in our sample are present in altogether 112 countries (for an overview see Table 3 in the Appendix).[18] Using darker color to indicate bigger numbers of affiliates, Figure 1 shows that affiliates are highly concentrated in member countries of the European Union, Russia, China, Brazil, Canada, and the United States, with a maximum of 2,443 affiliates for the average year located in the United States. At the other extreme are mainly African and some Asian countries with 3 or less affiliates in the average year. Using darker color to indicate higher values of average fixed and intangible assets per affiliate, Figure 2 suggests that countries such as China, Brazil, and the USA which host many affiliates also host larger affiliates, on average. However, also countries such as Algeria and Cameroon with on average only 14 and 4 affiliates per annum, respectively, receive similar amounts of fixed and intangible assets per affiliate.

While Figures 1 and 2 considered the number of affiliates and fixed and intangible assets per affiliate in the average year covered by host country, Figures 3 and 4 illustrate the geographic distribution of the number of German parent companies and the fixed and intangible assets per German parent company in the average year by host country. Overall, the number of parent companies at a location tends to be large where the number of affiliates is large, and assets per parent tend to be large where the number of affiliates per parent and/or the assets per affiliate are large in the average year. In countries such as Russia – colored dark-blue in Figure 1 but lighter-blue in Figure 3 – a relatively large number of affiliates is held by a

[16] Following Hall and Jones (1999) the capital stock at time t is generically defined as $K_t = (1-\delta)K_{t-1}+GFC_t$. Here, GFC_t is the gross fixed capital formation at constant US dollars of 2000 as reported in the World Bank's World Development Indices Database, and δ is the rate of depreciation, set at 0.133 (see, e.g., Leamer, 1984). Furthermore, we calculate the initial capital stock by $K_0 = \frac{GFC_0}{\delta+g_K}$, where g_{GFK} is the rate of growth of the capital stock, being set at 0.025, as in Bergstrand and Egger (2007).

[17] On average an affiliate is about 6.2 years in the sample.

[18] Figures 1-11 include only 92 of the 112 countries in the sample due to the confidentiality regulations of the Deutsche Bundesbank. This results in the deletion of 20 countries with less then 3 affiliates in an average year per country from our graphical representation. Nevertheless, all affiliates and 112 host countries are included in the estimation below.

relatively small number of parent firms. FDI (fixed and intangible assets) per parent company is on average highest in Cyprus, followed by the United States and China. Overall, most of and the biggest German MNEs mainly invest in the European Union, North America, Brazil, Russia, and China.

In a next step, we describe the closeness or proximity of German foreign affiliates and German FDI per firm and country in terms of three channels of interdependence: input (vertical upstream) proximity, output (vertical downstream) proximity, and geographic (horizontal) proximity. The values in Figures 5, 6, and 7 are calculated by multiplying each parent firm's weights matrix W_{ft}^{ℓ} by a vector of ones to obtain a measure of pure input, output, or geographic distance within its network of foreign affiliates. This yields a firm-f-specific measure of proximity in year t and dimension (or proximity channel) ℓ. In each country, we then calculate the average of this measure of proximity across all parents weighted by the number of affiliates they hold and the years they are present. This obtains an average measure of proximity of affiliates per country within the German affiliate network in dimension ℓ. In Figure 5 the average affiliate in darker-colored countries is closer in terms of inputs received from other members of its network than the average affiliate in lighter-colored countries. In Figure 6 the average affiliate in darker-colored countries is relatively closer to other affiliates of its network in terms of output delivered than in lighter-colored countries. Figures 5 and 6 suggest that input and output proximity are, in general, relatively similar across countries. Hence, well-connected affiliates through the downstream channel tend to be also well connected through the upstream channel. Nevertheless, there are some interesting differences. For instance, the average German affiliate in the United States is relatively more related to other entities within the average MNE in terms of inputs received than in terms of output delivered. This is consistent, e.g., with the global allocation of production of large German car manufacturers present in the United States. It generally makes sense to think about the US as being a large final market, and not being an intermediate country in the global value chain. A comparison of Figures 5 and 6 with Figure 7 suggests that there is an obvious difference between vertical (input-output) and horizontal (merely geographic) proximity. For instance, while affiliates in *Factory Asia* (Baldwin, 2007) and South America are well connected vertically, their horizontal proximity is relatively low. The opposite seems to be true for European countries, on average. Other interesting examples are countries like Uruguay or Namibia, which are both more integrated through the output channel. For Uruguay, this is consistent with the fact that many German multinationals provide financial services from Montevideo to affiliated entities located in South and Latin America. For Namibia, this is consistent with the fact that some German firms produce raw materials (e.g., cement) to be exported to other countries in Southern Africa.

Figures 8, 9, and 10 suggest a similar pattern for FDI (fixed and intangible assets).

5 Results

This section reports the parameter estimates and the consequences of counterfactual shocks in the foreign affiliate system based on the estimated model when relying on the specification outlined in Section 3. Table 2 summarizes parameter estimates on the different (endogenous) interdependency terms of FDI stock elsewhere in parent company f's network on the FDI stock at affiliate i. All regressions include affiliate-level (and, implicitly, parent-level) fixed effects as well as a full set of aggregate year effects.

In columns 1 to 5 in Table 2 we use four different variables to capture the channels of interdependence in foreign assets. First, $\overline{FDI}_{it}^{I}$ is the input-weighted FDI stock of other affiliates than i as defined above. Second, $\overline{FDI}_{it}^{O}$ is the output-weighted FDI stock of other affiliates than i. Third, $\overline{FDI}_{it}^{IO}$ is the input-plus-output-weighted FDI stock of other affiliates than i. Fourth, $\overline{FDI}_{it}^{D}$ is the inverse-(geographic-)distance-weighted FDI stock of other affiliates than i. The weighting matrices that apply to the interdependence terms are all maximum row-sum normalized to make obvious that the estimated coefficients on interdependence terms are in the admissible parameter space. Notice that this scalar-type normalization preserves the notion of absolute proximity in the affiliate network of any MNE. As suggested in Section 3.1, we use weighted exogenous regressors (applying the respective linkage-channel-specific weight) to instrument the interdependence terms (see Table 1 for those variables and the respective summary statistics). In what follows, the instruments consist of a full set of four instruments per linkage term. That is, input-interdependence, output-interdependence, and geography-interdependence are modeled separately, so that there are 12 instruments based on $\overline{Sales}_{it-1}^{\ell}$, $\overline{Employees}_{it-1}^{\ell}$, $\overline{Corporate\ Income\ Tax}_{it}^{\ell}$, $\overline{Competition}_{it-1}^{\ell}$ for $\ell \in I, O, D$.[19] While it has been shown above that the weighted exogenous variables can be used as optimal instruments, there might be a concern about the exclusion restrictions in the context of weighted variables measured at the level of the firm. We will address this by using lagged weighted affiliate characteristics as instruments for affiliate i but only affiliate characteristics of other multi-

[19] In an earlier version of the paper we have experimented more with the set of instruments and have shown that results are robust to alternative specifications and combinations of instruments. Notice that one could increase the instrument set by using higher-order powers of the linkage weights. However, the instrument quality deteriorates with the order of linkage weights and all that is needed here are only at least as many instruments as there are linkages in the model.

national firms in the same country and year that are not related to i and belong to another multinational firm.[20] Beside linkage terms and the mentioned affiliate- as well as time-specific effects, we condition on a number of control variables shown and summarized in Table 1.

The control variables affect affiliates' FDI as expected. First, larger sales and a bigger number of employees per affiliate have a positive effect on German MNEs' investment abroad. Second, a higher level of local (corporate) profit tax rates reduces investment. More precisely, a one-percentage-point increase in the tax rate ceteris paribus reduces local investment by -1.16% for the average German MNE. This magnitude is broadly in line with previous findings (for a meta-analysis see De Mooij and Ederveen, 2006). Third, a sound functioning of the financial sector in the host country of the investment, measured by the financial freedom variable, raises investment per affiliate there. Fourth, a higher inflation reduces local foreign investment per affiliate negatively, as does having a German competitor in the same sector and host country. The former reflects adverse temporal (or cyclical) macroeconomic conditions, the latter captures adverse structural (competitive) conditions. While the adverse competitive effect is quantitatively relatively small, it is statistically highly significant. Finally, an increase in a host country's capital-labor ratio (which measures both a relative capital abundance and the relative development of a host country) exerts a positive effect on investment while GDP, as a measure of the size of the host economy is positively related to investments.

A glance at the coefficients on the linkage terms in Table 2 suggests the following conclusions. First, horizontal (geographic) linkages matter to a smaller extent, whereas vertical linkages via input-output relations seem to matter more. There is clear evidence of positive interdependencies to affiliates which are downstream from their upstream network members. For affiliates which are upstream and close to their downstream members the opposite seems to be true. This is consistent with a U-shaped curve pattern in the context of the evolution of countries and industries (see Shin, Kraemer, and Dedrick, 2012, for an empirical application in the global electronics industry). This relationship suggests that the profitability is particularly high at the root or origin of the production process or product cycle (where the research intensity is high) and also at the end of it (where input costs are low and the service intensity is high). In a developed country such as Germany which is increasingly specialising on services, it is consistent with this pattern that firms seek to shift their activity towards

[20] We are not concerned that these affiliates may be affected by the same (exogenous) shocks as i. What is important is that neither affiliate i nor the firm controlling i may directly affect the characteristics of other firms in period $t-1$. In particular, the latter should be the case as outcome of affiliate i is measured in period t, and the instruments are measured in period $t-1$.

and maximize their profit margins at the end of the production line.

Our findings seem to be also in line with Alfaro, Antràs, Chor and Conconi (2015). The latter paper suggests that the elasticity of demand for a firm's final product, as well as the relative contractibility vis-à-vis stages located upstream or downstream from a given production stage, determine upstream or downstream integration choices. If inputs are not particularly easy to substitute, Alfaro et al. (2015) suggest that the incentive of a supplier to invest in a relationship-specific input is higher, the larger the investments by upstream suppliers. This is consistent with our finding of a positive relationship between investment of a given affiliate and investments of all other affiliates within the MNE if the affiliate is linked through the input channel. Moreover, while we cannot model the outsourcing decision, the findings in Alfaro et al. (2015) suggest that the integrated part of the total value chain for input-linked affiliates in our data tends to be more downstream. The negative interdependence found for affiliates linked through the output channel is in line with the assumption that the inputs supplied by these affiliates are characterized by a high substitutability, suggesting that the integrated part of the value chain we observe in our data for the output-linked affiliates is more up the stream. All this suggests that both goods produced and relationship-specific investments made along the value chain become more specialized and less substitutable.

Our findings finally confirm the results in Smarzynska Javorcik (2004), who shows that (positive) productivity spillovers from FDI to domestic firms mainly take place through backward linkages (through the intermediate input channel), rather than forward linkages. While our results support the view that such interdependencies also exist within MNEs and productive assets, there seem to be even negative effects on affiliates linked through the output or forward channel.[21]

Columns 3 and 4 present specifications with a different decay function about the spatial process and the impact of inverse distance. In particular, in column 3 we use the squared inverse distance, in column 4 the square root of the inverse distance. Once we specify alternative decay functions, the

[21] It is less straightforward to interpret our findings in the light of the learning model as suggested in Egger, Fahn, Merlo, and Wamser (2013) to explain international expansion patterns of affiliate networks. On the one hand, Egger, Fahn, Merlo, and Wamser (2013) model the extensive instead of, as in this paper, the intensive investment margin. On the other hand, Egger, Fahn, Merlo, and Wamser (2013) distinguish between sequential and simultaneous investments and find qualitative differences in their determinants. Since we focus on investments within given affiliates it is not possible to explicitly distinguish between the latter modes. However, as our results suggest interdependencies predominantly through vertical production linkages, the results suggest that proximity on a general level (here, mainly in terms of vertical linkages) matters for marginal investment decisions or for discrete investment project decisions even in a given affiliate network.

negative effect of $\overline{FDI}_{it}^{D}$ becomes insignificant. This confirms that vertical linkages seem to be more important for interdependence than geography. In column 5 we test the robustness of the internal-distance measure. Figure 7 suggests that average geographic proximity is lowest for affiliates in large countries like the U.S., Canada, Brazil or China. This may have to do with the fact that the average internal distance is used for affiliates within the same country. For this reason it is of interest to test whether our main results are affected by another weighting of affiliates within the same country. In the specification in column 5, we give all affiliates within a country the same weight, across all countries. Specifically, we set $w_{ijt}^{D0} = d_{ij}^{-1} = 1$ whenever affiliates i and j are located in the same country (implicitly assuming that intra-national distance plays no role). This alternative treatment of affiliates within the same country has no effect on our findings.

Column 6 shows results where we control for country-time effects. These results confirm the impact of the three main variables of interest, $\overline{FDI}_{it}^{I}$, $\overline{FDI}_{it}^{O}$, and $\overline{FDI}_{it}^{D}$. This shows that the estimated coefficients are not biased through unobserved country-specific variables. Of course, all variables measured at the level of countries and years are not identified in this specification.

While our focus is on the intensive margin of investment (the effect of marginal investment decisions at other locations on the level of investment at a given location), we explore the relative importance of adjustments at the intensive margin (changes in investment by old affiliates) vs. adjustments at the extensive margin (investment by new affiliates). Column 6 of table 2 distinguishes between an extensive and an intensive margin effect. For this, we assume different slope parameters on $\overline{FDI}_{it}^{I}$, $\overline{FDI}_{it}^{O}$, and $\overline{FDI}_{it}^{D}$, respectively, depending on whether an affiliate that contributes to the respective weighted variable is new (an extensive margin adjustment) or not (an intensive margin adjustment). The results suggest that (i) the input-output interdependence is driven by the extensive margin, while the coefficients on the intensive margin estimates show the same signs but are no longer statistically significant; (ii) the geographical interdependence is driven by the intensive margin. This results suggest that the impact of vertical integration decisions on investment across all affiliate in the network is more pronounced than that of horizontal integration decisions.

We finally run regressions (the basic specification shown in column 1) at the level of industries. This might indicate whether there exist heterogeneous spatial effects of horizontal foreign investment across industries. We plot the estimated coefficients on $\overline{FDI}_{it}^{D}$ by way of a kernel density plot (see Figure 11). The figure suggests that there is significant heterogeneity across sectors. Based on those sectors with sufficient observations, the average coefficient estimated $\overline{FDI}_{it}^{D}$ is clearly negative.[22] The results also reveal, however, that the effects may be positive, depending on the industry affiliate i is operating in. This is true for about one third of the sectors we analyze. On average, the negative substitution effect (as in export platform FDI models) dominates the positive effects of information spillovers.

6 Analyzing the consequences of tax shocks

Based on Specification I in Table 2, we may quantify the effect of a one-percentage-point (1ppt) decrease, for instance, in the corporate profit tax rate of country r, $r = 1, \cdots R$ ($\Delta\boldsymbol{\tau}^r = -0.01$) on the foreign affiliates' FDI stock as follows:

$$\Delta\mathbf{FDI} = (\mathbf{I} - \hat{\lambda}^I\mathbf{W}^I - \hat{\lambda}^O\mathbf{W}^O - \hat{\lambda}^D\mathbf{W}^D)^{-1}\hat{\beta}_\tau\Delta\boldsymbol{\tau}^r, \qquad (12)$$

where $\hat{\beta}_\tau$ is the estimated coefficient on the corporate tax rate (1,16 in our preferred specification) and $\Delta\boldsymbol{\tau}^r$ has entry (-0.01) only in rows corresponding to affiliates located in r and zeros elsewhere. Notice that the total effect in (12) takes into account that such a shock on i through $\Delta\boldsymbol{\tau}^r$ will not only induce direct (or local) effects on affiliate i, but it will induce indirect effects on other affiliates which will themselves induce indirect effects back on i. This is captured by the inverse $(\mathbf{I} - \hat{\lambda}^I\mathbf{W}^I - \hat{\lambda}^O\mathbf{W}^O - \hat{\lambda}^D\mathbf{W}^D)^{-1}$ in (12), which accounts for an infinite series of indirect effects within each parent's affiliate network.

The effects consistent with (12) may be visualized as follows. Define $\mathcal{N}_{rt}$ and $\mathcal{N}_{mt}$ as the *sets* of affiliates located in countries r and m, respectively, in year t. Let N_{rt} and N_{mt} be the respective *numbers* of affiliates in those countries in year t. And denote the total number of countries by R and the total number of affiliates in year t across all countries by N_t. Then, the average total effect of $\Delta\boldsymbol{\tau}^r$ on affiliates located in r is

$$N_{rt}^{-1}\sum_{i\in\mathcal{N}_{rt}}\Delta FDI_{it}^{r}. \qquad (13)$$

The average indirect effect of $\Delta\boldsymbol{\tau}^r$ on affiliates located outside of country r is

$$(N_t - N_{rt})^{-1}\sum_{m\neq r}\sum_{i\in\mathcal{N}_{mt}}\Delta FDI_{it}^{r}. \qquad (14)$$

The average indirect effect over all $\Delta\boldsymbol{\tau}^m, m \neq r$ on affiliates located in r

$$(R-1)^{-1}N_{rt}^{-1}\sum_{m\neq r}\sum_{i\in\mathcal{N}_{rt}}\Delta FDI_{it}^{m}. \qquad (15)$$

[22]Note that we cannot report more details of the sector-level regressions, since the Deutsche Bundesbank has specific requirements regarding the number of observations per firm, per market, and per sector.

For instance, Figure 12 illustrates the geographic pattern of the total effect as in (13) on the average affiliate in a country. Notice that we consider a shock in corporate profit tax rates in one country at a time. Clearly, the direct effect of that shock is always $(-1.16) \cdot (-0.01)$ so that the geographic pattern is entirely due to the heterogeneity in all three dimensions of proximity and the respective parameter weights on the channels in Specification I of Table 2. Figure 13 visualizes the total indirect effect from a shock in tax rates in the country of affiliate i on affiliates of the same parent company that are situated in other countries. The results in this figure are obtained as described in (14), averaging the outcome across all other countries (and firms as well as affiliates). Hence, this figure illustrates which host countries tend to be sources of larger or smaller spillovers on FDI in other countries. Finally, Figure 14 illustrates to which extent country-specific (one-at-a-time) shocks on corporate profit taxes in other countries spill over to affiliates in a given host country, on average. Formally, the results in this figure are obtained as described in (15). This figure illustrates which host countries tend to be recipients of larger or smaller spillovers from other countries on foreign direct investment. Due to the asymmetry in input-output tables and the heterogeneity in the sector membership across affiliates within a parent company, the host countries which tend to receive high average spillovers from shocks in foreign taxes abroad are not necessarily also strong sources of spillovers to affiliates in other countries (to see this, compare the shading of Figure 14 with that of Figure 13).

The strongest overall positive impacts of an independent negative shock to local profit tax rates in Figure 12 are found for China, the USA, and Brazil. The smallest impacts are found for Cyprus, Malta, and Luxembourg. Comparing the results of Figures 12 and 7 shows that spillovers are positive and strong mainly to neighboring countries, on average. However, an inspection of Table 2 suggests that the researcher would be misguided to conclude that the source of this pattern is mere geography, since we have seen that the actual channels are downward closeness and upward distance in input-output space. Conditioning on input-output relationships, mere geography has little to contribute to the geographic pattern of spillovers. Figure 13 suggests that shocks are particularly strongly (positively) transmitted by affiliates in the USA, China, and Japan to foreign affiliates and, to a somewhat lesser extent, by affiliates in Italy and Spain. On the other extreme, a reduction in profit tax rates in adjacent countries to Germany – such as Austria, Belgium, the Netherlands, and Switzerland – tends to induce negative effects on the rest of the affiliate network of German MNEs, on average. The main reason for this finding is that affiliates in these countries tend to be up the stream and technologically closer to other affiliates down the stream rather than to ones further up the stream. Also, they tend to be geographically close to other affiliates in the network which, on average, leads to negative spillovers from those countries. Figure 14 suggests that shocks on corporate profit taxes in other countries which spill over to affiliates in a given host country positively affect foreign direct investments in several emerging and South American economies. On the contrary, German MNEs' affiliates in several European countries tend to receive non-positive spillovers from a reduction of profit tax rates abroad.

Note that, when looking at Figures 7 and 10 alone, we could conclude that FDI, from a German perspective, to overseas countries is mainly related to horizontal FDI (since, for example, we observe a lot of German investments in the United States, but these investments are primarily standalone ones). The other figures, however, suggest that there are linkages between affiliates within an MNE's network beyond pure geography (using the example from above, this implies that there is intrafirm shipments to affiliates in the United States from affiliates that are close in terms of industry closeness rather than geographic closeness).

7 Conclusions

Using a census-type panel data-set of German parent firms and their affiliates from 1997-2009, this paper formulated a model to identify several channels of spillovers within the German parent firms' affiliates networks on the affiliate-specific foreign direct investments. Allowing for three channels of interdependence or spillovers – horizontal linkages (mere geography), vertical input linkages, and vertical output linkages – we find that horizontal linkages only matter to a limited extent, whereas vertical linkages are the main source of spillovers. Moreover, we find that spillovers from other affiliates are larger if an affiliate is technologically situated down the stream and strongly connected to affiliates further up the stream and if it is less strongly connected to affiliates further down the stream.

We use the regression results to quantify the magnitude of total effects of shocks, of spillover effects from and to affiliates across countries within the German multinational firm network. For illustrative purposes, we use a reduction in corporate profit tax rates by one-percentage point in one country at a time and calculate its predicted effect on foreign direct investments across affiliates. Overall, the findings are illustrative of non-trivial effects of policy shocks on the investments in a foreign affiliate network. Identical shocks on profit tax rates do not only lead to quantitatively but even to qualitatively different effects, depending on where they occur. The findings in this paper suggest that primarily the technological proximity in input-output space and less so the geography of an average MNE's affiliate network matters for the geographic heterogeneity of spillover and total effects of tax policy on foreign direct investment.

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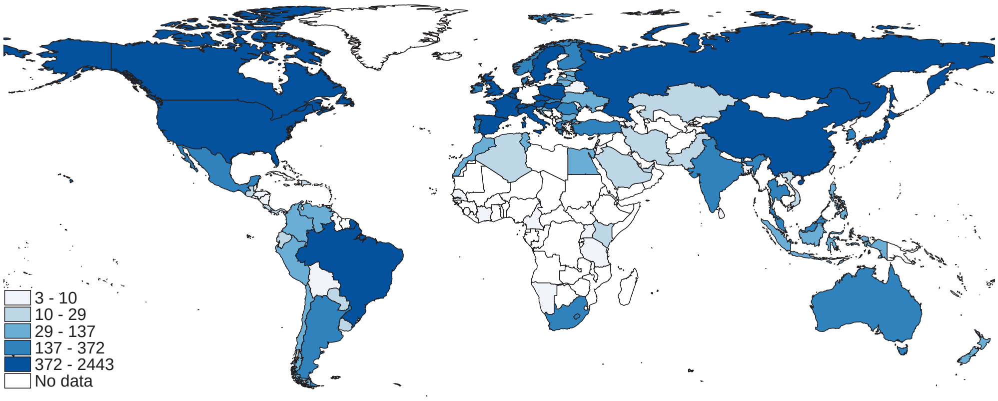
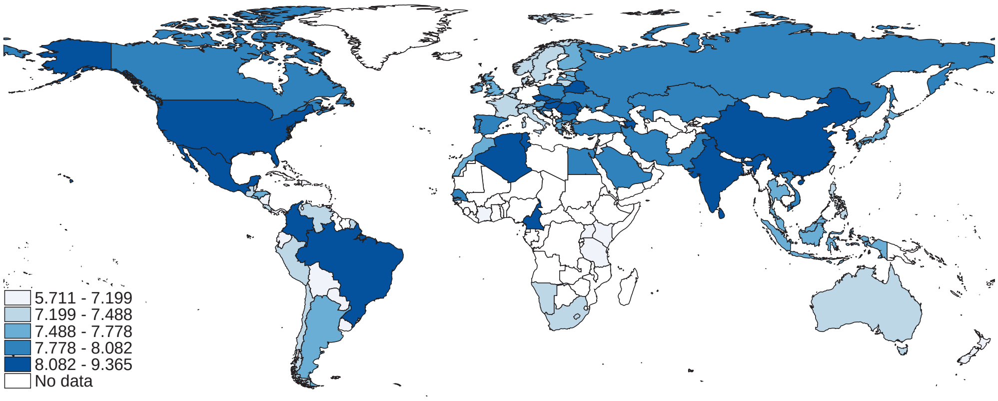
7.1 Descriptives

Figure 1: Average number of affiliates for the average year per country



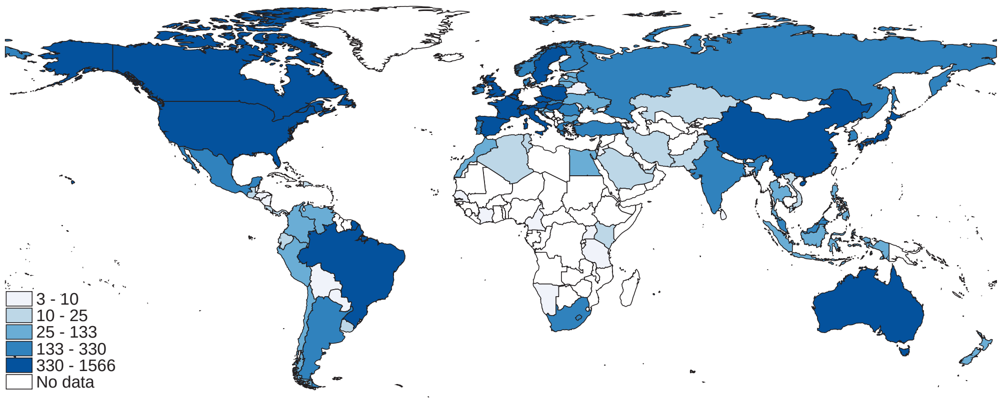
For 92 countries from 1997-2009. Each group in the legend represents 20% of the countries.

Figure 2: Average (log) fixed assets per affiliate for the average year per country



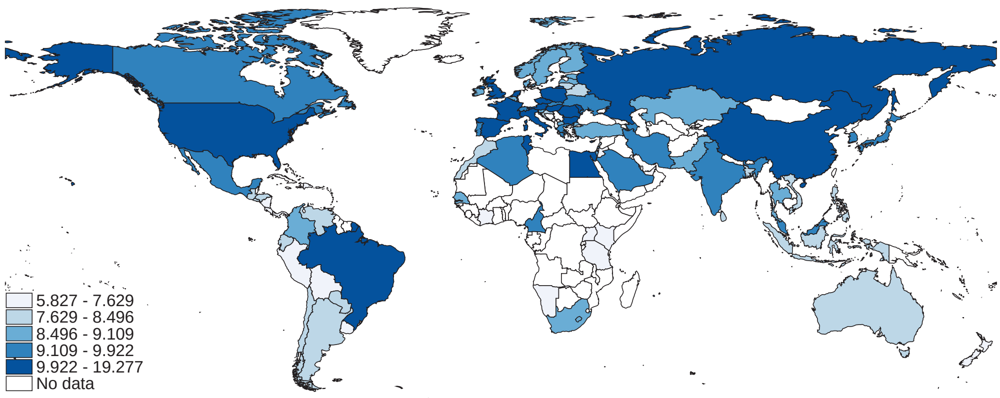
For 92 countries from 1997-2009. Each group in the legend represents 20% of the countries.

Figure 3: Average number of parent-firms for the average year per country



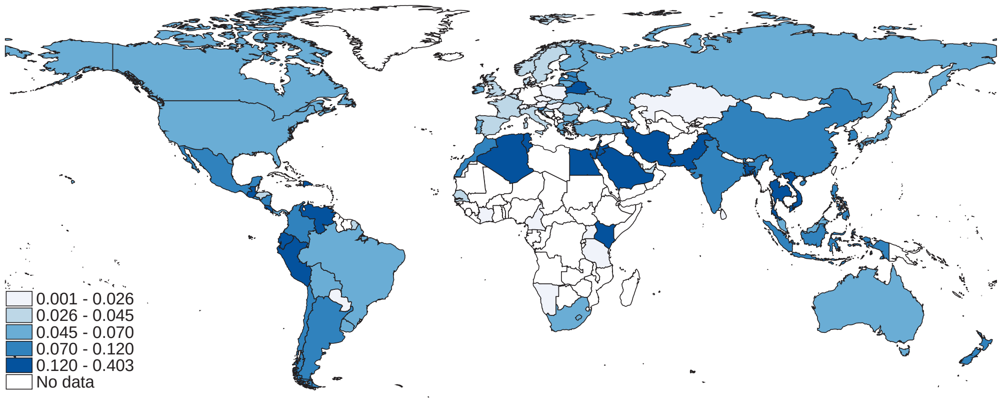
For 92 countries from 1997-2009. Each group in the legend represents 20% of the countries.

Figure 4: Average (log) fixed assets per parent-firms for the average year per country



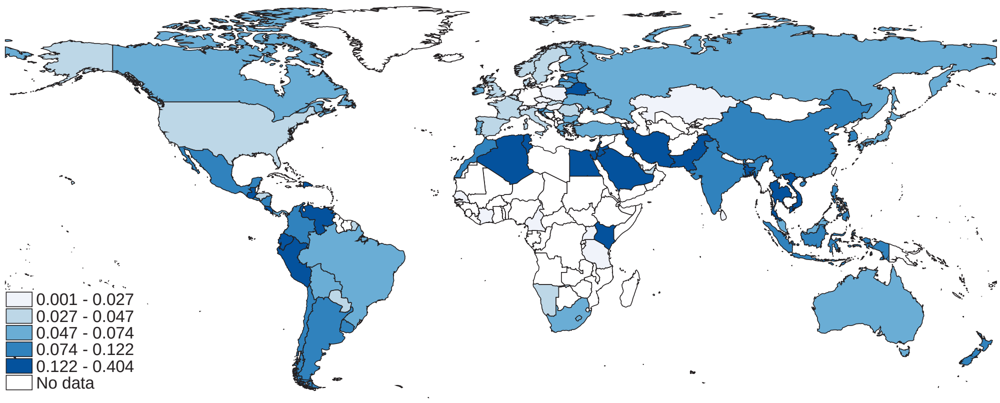
For 92 countries from 1997-2009. Each group in the legend represents 20% of the countries.

Figure 5: Average input proximity across all affiliates for the average firm per country



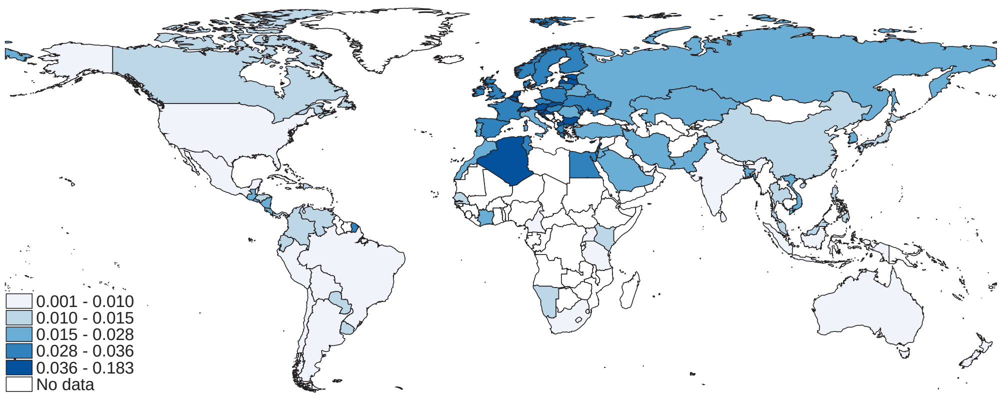
For 92 countries from 1997-2009. Each group in the legend represents 20% of the countries.

Figure 6: Average output proximity across all affiliates for the average firm per country



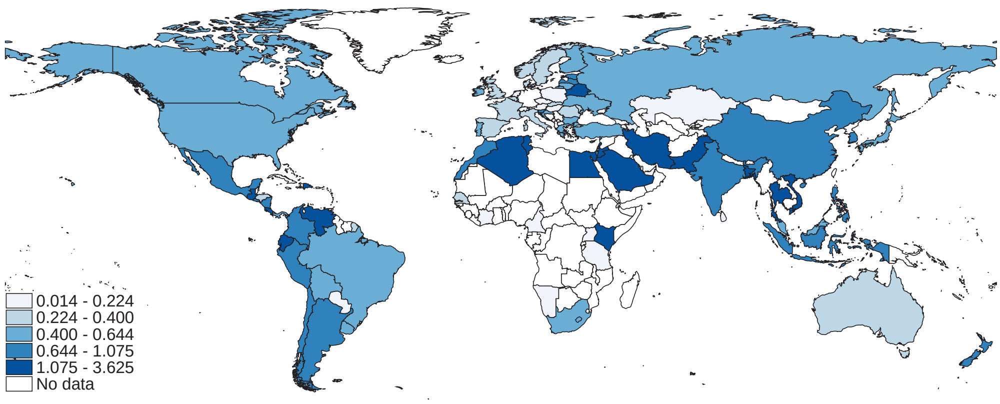
For 92 countries from 1997-2009. Each group in the legend represents 20% of the countries.

Figure 7: Average geographic proximity across all affiliates for the average firm per country



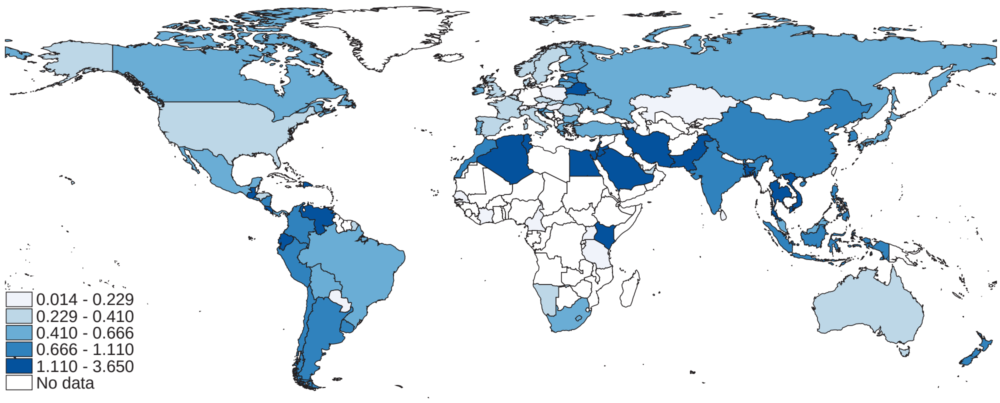
For 92 countries from 1997-2009. Each group in the legend represents 20% of the countries.

Figure 8: Average input-weighted (log) fixed assets proximity across all affiliates for the average firm per country



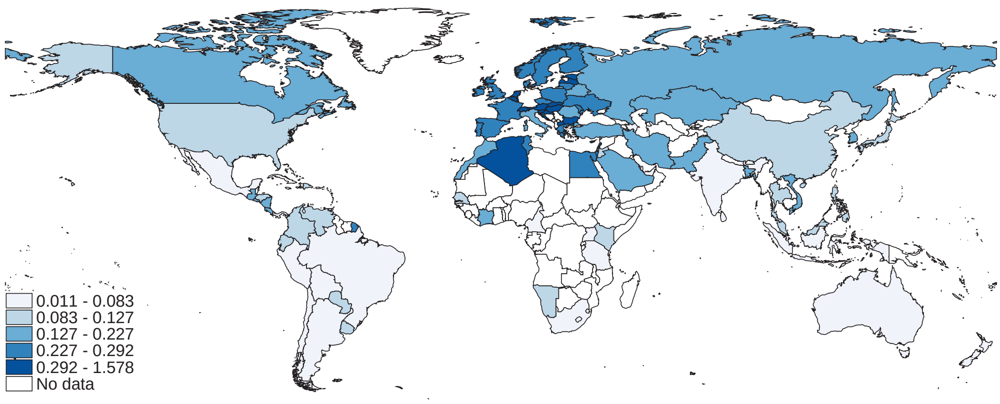
For 92 countries from 1997-2009. Each group in the legend represents 20% of the countries.

Figure 9: Average output-weighted (log) fixed assets proximity across all affiliates for the average firm per country



For 92 countries from 1997-2009. Each group in the legend represents 20% of the countries.

Figure 10: Average geography-weighted (log) fixed assets proximity across all affiliates for the average firm per country



For 92 countries from 1997-2009. Each group in the legend represents 20% of the countries.

7.2 Summary statistics and regression output

Table 1: Summary statistics

Main variables	**Mean**	**Std. Dev.**
FDI_{it}	7.725	2.051
$Sales_{it-1}$	3.109	1.353
$Employees_{it-1}$	4.475	1.417
$Corporate\ Income\ Tax_{it}$	0.314	0.072
$Financial\ Freedom_{it}$	67.703	18.123
$Inflation_{it}$	3.343	6.436
$Capital - LaborRatio_{it}$	10.553	0.974
GDP_{it}	27.417	1.375
$Competition_{fit-1}$	110.72	156.21
Interdependence terms	**Mean**	**Std. Dev.**
$\overline{FDI}^{I}_{it}$	0.390	1.134
$\overline{FDI}^{O}_{it}$	0.401	1.134
$\overline{FDI}^{D}_{it}$	0.241	0.483
$\overline{FDI}^{Iint}_{it}$	0.348	1.071
$\overline{FDI}^{Iext}_{it}$	0.041	0.412
$\overline{FDI}^{Oint}_{it}$	0.358	1.070
$\overline{FDI}^{Oext}_{it}$	0.042	0.414
$\overline{FDI}^{Dint}_{it}$	0.210	0.454
$\overline{FDI}^{Dext}_{it}$	0.030	0.201
Instruments	**Mean**	**Std. Dev.**
$\overline{Sales}^{I}_{it-1}$	0.435	1.149
$\overline{Employees}^{I}_{it-1}$	0.497	1.330
$\overline{Corporate\ Income\ Tax}^{I}_{it}$	0.014	0.038
$\overline{Competition}^{I}_{it-1}$	2.676	5.659
$\overline{Sales}^{O}_{it-1}$	0.443	1.141
$\overline{Employees}^{O}_{it-1}$	0.508	1.322
$\overline{Corporate\ Income\ Tax}^{O}_{it}$	0.014	0.038
$\overline{Competition}^{O}_{it-1}$	2.536	5.335
$\overline{Sales}^{IO}_{it-1}$	0.439	1.144
$\overline{Employees}^{IO}_{it-1}$	0.503	1.325
$\overline{Corporate\ Income\ Tax}^{IO}_{it}$	0.014	0.038
$\overline{Competition}^{IO}_{it-1}$	2.607	5.461
$\overline{Sales}^{D}_{it-1}$	0.311	0.653
$\overline{Employees}^{D}_{it-1}$	0.346	0.718
$\overline{Corporate\ Income\ Tax}^{D}_{it}$	0.009	0.017
$\overline{Competition}^{D}_{it-1}$	2.65	5.479

N = 139,696

Minimum and maximum values are not displayed due to the confidentiality rules of the Deutsche Bundesbank.

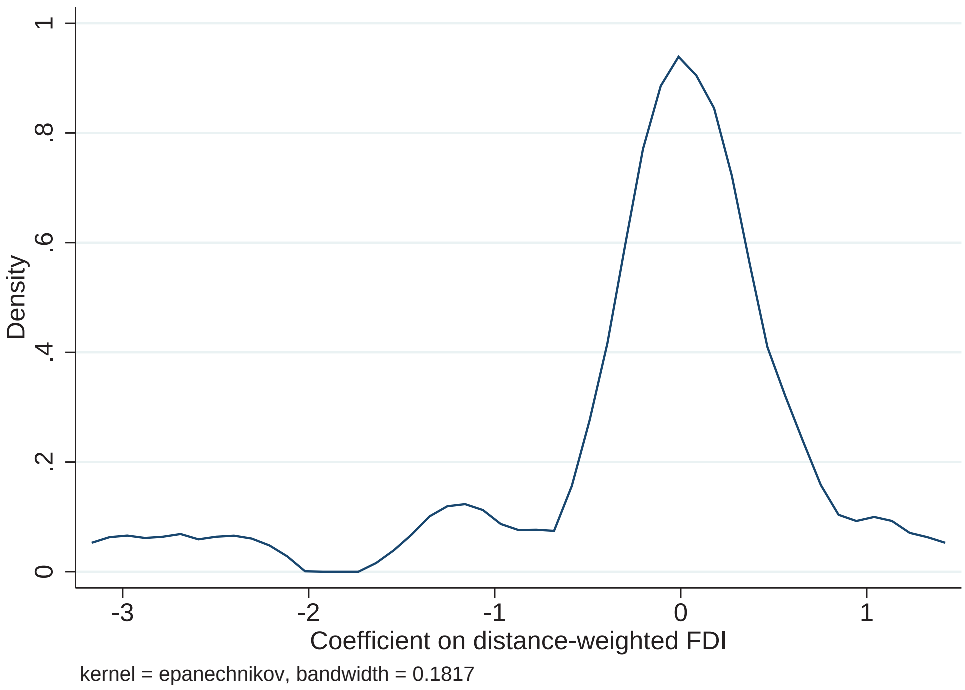
Table 2: Analysis of German MNEs' foreign investments

	Basic spec. I	*Basic spec. II*	*Inv. Dist. decay²*	*Inv. Dist. $\sqrt{decay}$*	*No Int. Dist.*	*Country-time eff.*	*Ext. & int. margin*
$\overline{FDI}_{it}^{I}$	0.195***		0.198***	0.195***	0.188***	0.557***	
	(0.068)		(0.068)	(0.068)	(0.068)	(0.073)	
$\overline{FDI}_{it}^{Iint}$							0.105
							(0.082)
$\overline{FDI}_{it}^{Iext}$							2.564***
							(0.882)
$\overline{FDI}_{it}^{O}$	-0.161**		-0.167**	-0.162**	-0.154**	-0.382**	
	(0.068)		(0.068)	(0.068)	(0.068)	(0.072)	
$\overline{FDI}_{it}^{Oint}$							-0.072
							(0.082)
$\overline{FDI}_{it}^{Oext}$							-2.574***
							(0.885)
$\overline{FDI}_{it}^{D}$	-0.038*	-0.042**	-0.057	-0.013	-0.035**	-0.089***	
	(0.020)	(0.019)	(0.049)	(0.014)	(0.014)	(0.020)	
$\overline{FDI}_{it}^{IO}$		0.033***					
		(0.008)					
$\overline{FDI}_{it}^{Dint}$							-0.041**
							(0.020)
$\overline{FDI}_{it}^{Dext}$							-0.116
							(0.109)
$Sales_{it-1}$	0.180***	0.180***	0.180***	0.180***	0.180***	0.244***	0.174***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.007)	(0.010)
$Employees_{it-1}$	0.335***	0.336***	0.335***	0.335***	0.335***	0.680***	0.337***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.009)	(0.012)
$Corp.\ Inc.\ Tax_{it}$	-1.160***	-1.164***	-1.152***	-1.153***	-1.153***		-1.148***
	(0.155)	(0.155)	(0.155)	(0.155)	(0.155)		(0.155)
$Financial\ Freed._{it}$	0.002***	0.002***	0.002***	0.002***	0.002***		0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)		(0.001)
$Inflation_{it}$	-0.005**	-0.005**	-0.005**	-0.005**	-0.005**		-0.005**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)		(0.002)
$Cap. - Lab.Ratio_{it}$	0.181***	0.177***	0.183***	0.181***	0.186***		0.179***
	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)		(0.067)
GDP_{it}	0.119*	0.120*	0.120*	0.120*	0.130**		0.117*
	(0.066)	(0.066)	(0.066)	(0.066)	(0.066)		(.067)
$Competition_{it-1}$	- 0.0004***	-0.0004***	-0.0004***	-0.0004***	0.0004***	-0.003***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year dummies	yes	yes	yes	yes	yes	no	yes
R^2	0.103	0.103	0.103	0.103	0.103	0.458	0.093
N	134,702	134,702	134,702	134,702	134,702	139,561	134,702

Notes: FE2SLS estimations (see Section 3.1); t-statistics in parentheses. * ($p < 0.05$), ** ($p < 0.01$), *** ($p < 0.001$). Our estimation sample (unbalanced panel) includes 21,598 foreign affiliates of German MNEs in 112 different countries over the time period 1997 to 2009. The dependent variable is FDI_{fit}, reported in logs of million Euros.

7.3 Industry-specific coefficients

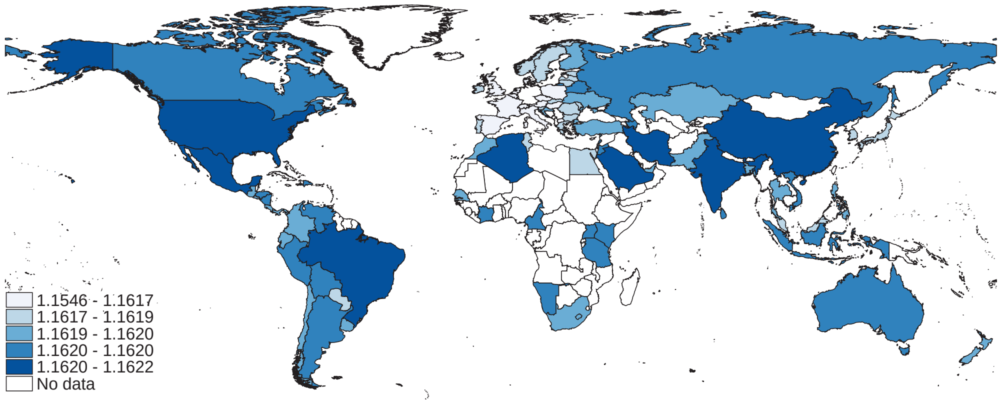
Figure 11: Density plot



The kernel density plot depicts estimated coefficients on $\overline{FDI}_{it}^{D}$, for each industry in which respective affiliates operate in separately. The mean over all parameters is -0.179, the standard deviation is 0.872.

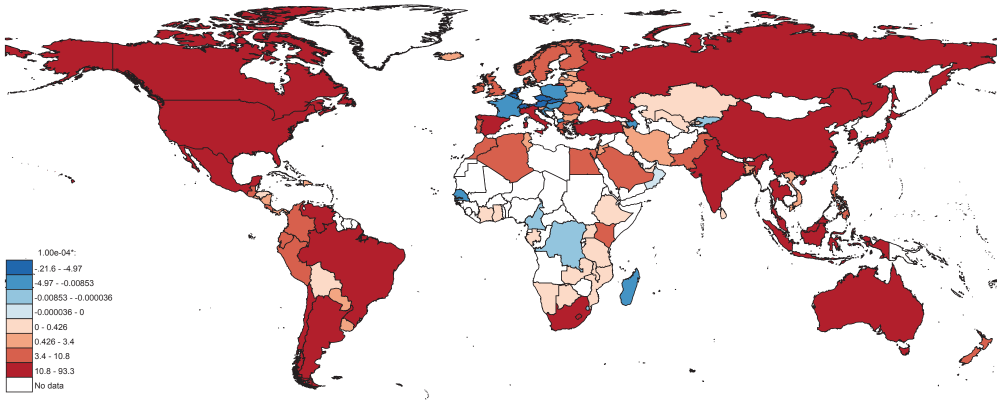
7.4 Quantification of direct and indirect effects of a one-percentage-point decrease in the corporate tax rate per country

Figure 12: Total (direct plus indirect) effect of a one-percentage-point tax reduction per country on the average affiliate there



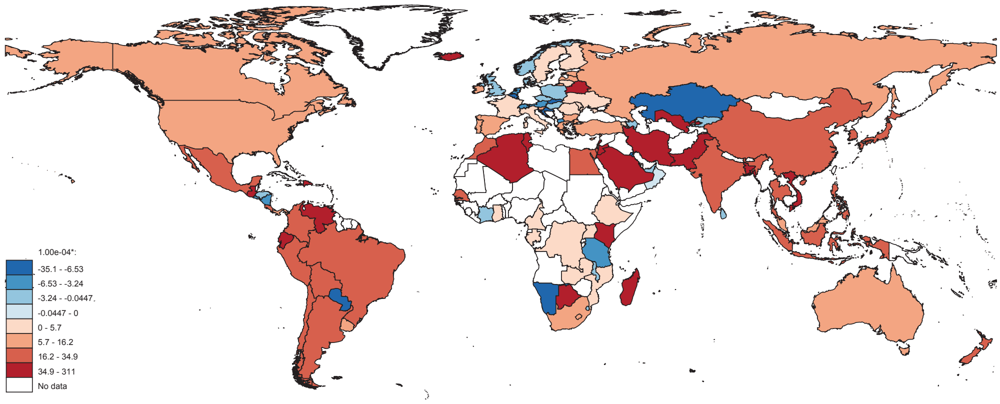
For 92 countries from 1997-2009

Figure 13: Total (indirect) effect of a one-percentage-point tax reduction per country on other affiliates outside of the country reducing the tax rate



For 112 countries from 1997-2009

Figure 14: Total (indirect) effect of a one-percentage-point tax reduction from other countries (one at a time) on the average affiliate per country



For 112 countries from 1997-2009

7.5 Overview tables

Table 3: Countries in the sample by continent

Continent	Country	Code	*a)*	Continent	Country	Code	*a)*
Africa	Algeria	DZA	0	Asia	Israel	ISR	0
Africa	Botswana	BWA	1	Asia	Japan	JPN	0
Africa	Cameroon	CMR	0	Asia	Jordan	JOR	0
Africa	Democ. Rep. of the Congo	COD	1	Asia	Kazakhstan	KAZ	0
Africa	Egypt	EGY	0	Asia	Kuwait	KWT	1
Africa	Ethiopia	ETH	1	Asia	Kyrgyzstan	KGZ	1
Africa	Gabon	GAB	1	Asia	Lebanon	LBN	0
Africa	Ghana	GHA	1	Asia	Malaysia	MYS	0
Africa	Ivory Coast	CIV	0	Asia	Oman	OMN	1
Africa	Kenya	KEN	0	Asia	Pakistan	PAK	0
Africa	Madagascar	MDG	1	Asia	Philippines	PHL	0
Africa	Malawi	MWI	1	Asia	Saudi Arabia	SAU	0
Africa	Mauritius	MUS	0	Asia	Singapore	SGP	0
Africa	Morocco	MAR	0	Asia	South Korea	KOR	0
Africa	Mozambique	MOZ	1	Asia	Sri Lanka	LKA	0
Africa	Namibia	NAM	0	Asia	Thailand	THA	0
Africa	Senegal	SEN	0	Asia	Turkey	TUR	0
Africa	South Africa	ZAF	0	Asia	Un. Arab Emirates	ARE	0
Africa	Swaziland	SWZ	1	Asia	Uzbekistan	UZB	1
Africa	Tunisia	TUN	0	Asia	Vietnam	VNM	0
Africa	Uganda	UGA	0	Europe	Austria	AUT	0
Africa	Un. Rep. of Tanzania	TZA	0	Europe	Belarus	BLR	0
Africa	Zambia	ZMB	1	Europe	Belgium	BEL	0
Americas	Argentina	ARG	0	Europe	Bulgaria	BGR	0
Americas	Barbados	BRB	1	Europe	Croatia	HRV	0
Americas	Bolivia	BOL	0	Europe	Czech Republic	CZE	0
Americas	Brazil	BRA	0	Europe	Denmark	DNK	0
Americas	Canada	CAN	0	Europe	Estonia	EST	0
Americas	Chile	CHL	0	Europe	Finland	FIN	0
Americas	Colombia	COL	0	Europe	France	FRA	0
Americas	Costa Rica	CRI	0	Europe	Greece	GRC	0
Americas	Dominican Rep.	DOM	0	Europe	Hungary	HUN	0
Americas	Ecuador	ECU	0	Europe	Iceland	ISL	1
Americas	El Salvador	SLV	0	Europe	Ireland	IRL	0
Americas	Guatemala	GTM	0	Europe	Italy	ITA	0
Americas	Honduras	HND	0	Europe	Latvia	LVA	0
Americas	Mexico	MEX	0	Europe	Lithuania	LTU	0
Americas	Nicaragua	NIC	0	Europe	Luxembourg	LUX	0
Americas	Panama	PAN	0	Europe	Macedonia	MKD	0
Americas	Paraguay	PRY	0	Europe	Malta	MLT	0
Americas	Peru	PER	0	Europe	Moldova	MDA	0
Americas	The Bahamas	BHS	1	Europe	Netherlands	NLD	0
Americas	Trinidad & Tobago	TTO	1	Europe	Norway	NOR	0
Americas	Un. States of America	USA	0	Europe	Poland	POL	0
Americas	Uruguay	URY	0	Europe	Portugal	PRT	0
Americas	Venezuela	VEN	0	Europe	Romania	ROU	0
Asia	Armenia	ARM	1	Europe	Russia	RUS	0
Asia	Azerbaijan	AZE	0	Europe	Slovakia	SVK	0
Asia	Bahrain	BHR	1	Europe	Slovenia	SVN	0
Asia	Bangladesh	BGD	0	Europe	Spain	ESP	0
Asia	China	CHN	0	Europe	Sweden	SWE	0
Asia	Cyprus	CYP	0	Europe	Switzerland	CHE	0
Asia	Hong Kong S.A.R.	HKG	0	Europe	Ukraine	UKR	0
Asia	India	IND	0	Europe	United Kingdom	GBR	0
Asia	Indonesia	IDN	0	Oceania	Australia	AUS	0
Asia	Iran	IRN	0	Oceania	New Zealand	NZL	0

There is a total of 112 countries in the sample. The column Code refers to ISO-3 codes. ***a)***: Countries indicated by 1 do not appear in Figures 1-11 of the paper, as they are based on less than three observations and therefore not released for display according to the confidentiality regulations of the Deutsche Bundesbank.

Table 4: Merged industry classifications (NACE/CPA)

No.[a]	Economic sectors (Bundesbank)	NACE	CPA	Individual goods (Statistisches Bundesamt)	No.[b]
1	Agriculture, hunting and related service activities	100	1	Erzeugnisse der Landwirtschaft und Jagd	1
2	Forestry, logging and related service activities	200	2	Forstwirtschaftliche Erzeugnisse und DL	2
3	Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing*	500	5	Fische und Fischereierzeugnisse	3
4	Mining of coal and lignite, extraction of peat	1000	10	Kohle und Torf	4
5	Extraction of crude petroleum and natural gas, service activities incidental to oil and gas extraction*	1100	11	Erdöl, Erdgas, DL für Erdöl-, Erdgasgewinnung	5
6	Mining of uranium and thorium ores	1200	12	Uran- und Thoriumerze	6
7	Mining	1300	13	Erze	7
8	Mining and quarrying, other mining	1400	14	Steine und Erden, sonstige Bergbauerzeugnisse	8
9	Manufacturing of food and beverages	1500	15.1 - 15.8	Nahrungs- und Futtermittel	9
			15.9	Getränke	10
10	Manufacture of tobacco products	1600	16	Tabakerzeugnisse	11
11	Manufacture of textiles	1700	17	Textilien	12
12	Manufacture of textile products*	1800	18	Bekleidung	13
13	Manufacture of leather and leather products*	1900	19	Leder und Lederwaren	14
14	Manufacture of wood and wood products*	2000	20	Holz; Holz-, Kork-, Flechtwaren (ohne Möbel)	15
15	Manufacture of pulp paper and paper products	2100	21.1	Holzstoff, Zellstoff, Papier, Karton und Pappe	16
			21.2	Papier-, Karton- und Pappewaren	17
16	Publishing, printing and reproduction of recorded media*	2200	22.1	Verlagserzeugnisse	18
			22.2 - 22.3	Druckerzeugnisse, bespielte Ton-, Bild- und Datenträger	19
17	Manufacture of coke, refined petroleum products and nuclear fuel*	2300	23	Kokereierzeugnisse, Mineralölerzeugnisse, Spalt- und Brutstoffe	20
18	Manufacture of pharmaceutical products	2440	24.4	Pharmazeutische Erzeugnisse	21
19	Manufacture of chemicals and chemical products	2400	24(ohne 24.4)	Chemische Erzeugnisse (ohne pharmazeutische Erzeugnisse)	22
20	Manufacture of rubber and plastic products	2500	25.1	Gummiwaren	23
			25.2	Kunststoffwaren	24
21	Manufacture of non metallic mineral products	2600	26.1	Glas und Glaswaren	25
			26.2 - 26.8	Keramik, bearbeitete Steine und Erden	26
22	Manufacture of basic metals	2700	27.1 - 27.3	Roheisen, Stahl, Rohre und Halbzeug daraus	27
			27.4	NE-Metalle und Halbzeug daraus	28
			27.5	Giessereierzeugnisse	29
23	Manufacture of metal products	2800	28	Metallerzeugnisse	30
24	Manufacture of machinery and equipment n.e.c.	2900	29	Maschinen	31
25	Manufacture of office machinery and computers	3000	30	Büromaschinen, Datenverarbeitungsgeräte und -einrichtungen	32
26	Manufacture of electrical machinery and apparatus n.e.c.	3100	31	Geräte der Elektrizitätserzeugung, -verteilung u.ä.	33
27	Manufacture of radio, television and communication equipment and apparatus	3200	32	Nachrtechn., Rundf.- und Fernsehgeräte, elektron. Bauelemente	34
28	Manufacture of medical, precision and optical instruments, watches and clocks	3300	33	Medizin-, mess-, regelungstechn., optische Erzeugnisse; Uhren	35
29	Manufacture of motor vehicles, trailers and semi-trailers	3400	34	Kraftwagen und Kraftwagenteile	36
30	Manufacture of other transport equipment (only until 2004) from 2005 onwards 3510,3520,3530, 3540,3550	3500	35	Sonstige Fahrzeuge (Wasser-, Schienen-, Luftfahrzeuge u.a.)	37

[a]: Consecutive sector number introduced for the present analysis. [b]: Consecutive sector number used in the input-output tables (Statistisches Bundesamt).

Table 4: Cont'd: Merged industry classifications (NACE/CPA)

No.[a]	Economic sectors (Bundesbank)	NACE	CPA	Individual goods (Statistisches Bundesamt)	No.[b]
31	Manufacure of furniture, manufacturing n.e.c.	3600	36	Möbel, Schmuck, Musikinstrumente, Sportgeräte, Spielwaren u.ä.	38
32	Recycling	3700	37	Sekundärrohstoffe	39
33	Electricity, gas, steam and hot water supply	4000	40.1, 40.3	Elektrizität, Fernärme, DL der Elektrizitäts- u. Fernwärmeversorgung	40
			40.2	Gase, DL der Gasversorgung	41
34	Collection, purification and distribution of water	4100	41	Wasser und DL der Wasserversorgung	42
35	Construction sector	4500	45.1 - 45.2	Vorb. Baustellenarbeiten, Hoch- und Tiefbauarbeiten	43
			45.3 - 45.5	Bauinstallations- und sonstige Bauarbeiten	44
36	Sale, repair of motor vehicles; retail sale of automotive fuel	5000	50	Handelsleist. mit Kfz; Rep. an Kfz; Tankleistungen	45
37	Wholesale trade and commission trade (except of motor vehicles and motorcycles)	5100	51	Handelsvermittlungs- und Groähandelsleistungen	46
38	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	5200	52	Einzelhandelsleistungen; Reparatur an Gebrauchsgütern	47
39	Hotels and restaurants	5500	55	Beherbergungs- und Gaststätten-DL	48
40			60.1	Eisenbahn-DL	49
	Land transport; transport via pipelines	6000	60.2 - 60.3	Sonst. Landv.leistungen, Transportleistungen in Rohrfernleitungen	50
41	Water transport	6100	61	Schifffahrtsleistungen	51
42	Air transport	6200	62	Luftfahrtleistungen	52
43	Supporting and auxiliary transport activities; activities of travel agencies	6300	63	DL bezüglich Hilfs- und Nebentätigkeiten für den Verkehr	53
44	Post and telecommunications (only until 2004) from 2005 onwards 6410, 6420.	6400	64	Nachrichtenübermittlungs-DL	54
45	Other credit institutions	6560	65	DL der Kreditinstitute	55
46	Insurance and pension funding, except compulsory social security.	6600	66	DL der Versicherungen (ohne Sozialversicherung)	56
47	Activities auxiliary to financial intermediation	6700	67	DL des Kredit- und Versicherungshilfsgewerbes	57
48	Housing enterprises, Other real estate activities	7050, 7060	70	DL des Grundstücks- und Wohnungswesens	58
49	Renting of machinery and equipment without operator and of personal and household goods	7100	71	DL der Vermietung beweglicher Sachen (ohne Personal)	59
50	Computer and related activities	7200	72	DL der Datenverarbeitung und von Datenbanken	60
51	Research and development	7300	73	Forschungs- und Entwicklungsleistungen	61
52	Accounting, book-keeping and auditing activities; tax consultancy (2005 on)	7412	74	Unternehmensbezogene DL	62
53	Federal government, Federal states, Local government and local authority associations	7560, 7570, 7580	75.1 - 75.2	DL der öffentlichen Verwaltung, Verteidigung	63
	Social security and employment promotion	7590	75.3	DL der Sozialversicherung	64
54	Education	8000	80	Erziehungs- und Unterrichts-DL	65
55	Health and social work, excluding non-profit organisations serving households	8500	85	DL des Gesundheits-, Veterinär- und Sozialwesens	66
56	Sewage and refuse disposal, sanitation and similar activities*	9000	90	Abwasser-, Abfallbeseitigungs- u. sonst. Entsorgungsleistungen	67
57	Activities of other membership organisations, excl. non-profit organisations serving households	9100	91	DL von Interessenvertretungen, Kirchen u.ï£¡.	68
58	Recreational, cultural and sporting activities, excl. non-profit org. serving households (only until 2004). from 2004 onwards 9210, 9220, 9230, 9240, 9250, 9260, 9270	9200	92	Kultur-, Sport- und Unterhaltungs-DL	69
59	Other service activities n.e.c., excluding non-profit organisations serving households	9300	93	Sonstige DL	70
60	Private households with employed persons, Other households	9550, 9560	95	DL privater Haushalte	71

[a]: Consecutive sector number introduced for the present analysis. [b]: Consecutive sector number used in the input-output tables (Statistisches Bundesamt).