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Aggregation Issues of Foreign Direct Investment Estimation in an Interdependent World

Helen Naughton[1], *Pehr-Johan Norbäck*[2] *and Ayça Tekin-Koru*[3]
[1]*Department of Economics, University of Montana, Missoula, MT, USA,* [2]*Research Institute of International Economics (IFN), Stockholm, Sweden, and* [3]*Department of Business Administration, TED University, Ankara, Turkey*

1. INTRODUCTION

FROM David Ricardo to the present day, economics literature has explained the existence of international trade using differences in technology, factor endowments, tastes or some combination of these. This two-century long journey produced many theories resulting in regularities that apply to reasonably homogeneous groups of products, firms, industries or even countries. However, there exists considerable heterogeneity at every level. Different entities behave differently across different boundaries, space and time. In terms of empirical research, this means recognising aggregation problems and perhaps offering solutions.

Heterogeneity across multinational corporations (MNCs) conducting foreign direct investment (FDI) is very extensive as well,[1] and there is no easy or obvious fix to dealing with aggregation problems in FDI. However, the massive increase in the availability of data on individual firms over sequential time periods coupled with the rapid rise in computing power makes it possible to implement models that are necessary for understanding the impact of FDI heterogeneity in aggregation.

This paper attempts to understand FDI heterogeneity and offers useful insights about aggregation issues in FDI estimations by carrying out an empirical analysis with rich, affiliate-level data on sales activities of Swedish MNCs around the globe in manufacturing sectors from 1965 to 1998.

Historically, the empirical FDI literature has used data combined over FDI types (horizontal, vertical, complex) often aggregated to country level and limited to a subset of the world mostly due to data unavailability. Running regressions on aggregate data is appropriate if one is interested in the aggregate model. However, most of the FDI theory is written for the firms choosing affiliate-level activity. In this case, the researcher faces the widely recognised problem of ecological fallacy, which occurs when results based on aggregate, grouped data are applied to the individual entities that form the groups being studied (Openshaw, 1984). The modifiable areal unit problem (MAUP) is perhaps one of the most well-known forms of ecological fallacy (Harris, 2006). MAUP occurs when results change depending on the definition of modifiable and arbitrary areal data units.

MAUP is composed of the scale problem and the zoning problem (Fotheringham and Wong, 1991). The scale problem arises when the same data set is aggregated at different scales in a system where these units are modifiable. The textbook example from the

[1] See Melitz (2003), Helpman et al. (2004), Greenaway and Kneller (2007), Melitz and Ottaviano (2008), and Yeaple (2009) for a review of firm heterogeneity in FDI.

geography literature is the successive aggregation of individuals into postcodes, neighbourhoods, regions and districts. In our case, the scale problem refers to the variation in results as units of observation (affiliates) are aggregated into fewer and larger units (firms, industries, countries) for analysis. The zoning problem arises because multitude of zones can be formed and used at any given scale by the researcher with different results being obtained by simply changing the boundaries of the zones. The zoning problem may not directly apply to our case because affiliates, in the empirical FDI literature, are not aggregated into arbitrary entities by researchers. Most often than not, they are aggregated to firms, industries and countries. Therefore, in this paper, we examine the prevalence only of the scale problem in the FDI estimations.

Using spatial econometrics and data on Swedish MNCs' affiliate-level sales activity, we first evaluate evidence of different motivations for FDI. As proxy for complex FDI theory, we use third-country sales; as proxy for horizontal FDI, we use host–country sales; and as proxy for vertical FDI, we use exports back to Sweden. Affiliate, firm and country-level analyses then offer links to previous literature and determine the consequences of using aggregated data.

Our results indicate that the multilayered nature of aggregation in FDI matters for empirical analysis. Affiliates are nested within a hierarchy and FDI is determined by both the characteristics of the affiliate and the level of nesting. For host-country and third-country affiliate sales, which dominate affiliate sales, we find a negative spatial lag that supports the export-platform theory. For affiliate exports back to Sweden, we find a positive spatial lag providing evidence of agglomeration of vertical production activities.

In this paper, inspired by a widely recognised aggregation problem in the geography literature we hope to increase our understanding of FDI heterogeneity and offer useful insights about aggregation issues in FDI estimations. The potential contributions of this paper to the economics literature are twofold.

First, we provide evidence of a severe scale problem in the FDI estimations when microdata are sequentially aggregated from affiliate level to firm and country level. Briant et al. (2010) have shown that scale effect jeopardises the estimations of gravity equations more than that of wage equations in their paper where they investigate the magnitude of the distortions arising from MAUP using French zones. Taking it up to the international level and using global network of Swedish MNCs, at the affiliate level, we estimate negative statistically significant spatial spillovers that decrease in magnitude when data are aggregated to firm level and finally disappear or flip to positive signs in country-level analyses.

Second, we contribute to a new line of FDI literature, which tries to uncover mechanisms through which multiproduct multinationals behave in global markets (Baldwin and Ottaviano, 2001; Eckel and Neary, 2010; Yeaple, 2013; Eckel et al., 2015). In particular, we expand the literature on multiproduct firms to understand the mechanisms through which the aggregation bias in FDI estimations emerge, and present a simple multiproduct multinational firm model of export-platform FDI and show that aggregation of individual units into larger units in the estimations hides the effects of intrafirm competition which causes variation in results from one scale to the other.

More specifically, we find evidence for aggregation bias for local sales and exports to third markets, which are proxies for horizontal FDI and export-platform FDI. For exports back to Sweden, which can be viewed as proxy for vertical FDI, aggregation bias is less apparent. However, since local sales and exports to third countries dominate MNEs' host country sales, one might suspect that aggregation bias is present in many of the studies that use aggregate FDI data.[2]

The rest of the paper is as follows: Section 2 discusses the aggregation of FDI over integration strategies and space while presenting the previous literature in the backdrop. Section 3 illustrates how aggregation bias (i.e. the scaling problem) can arise in a simple setting with multiproduct firms. Section 4 describes the spatial econometrics and the variables used in our empirical analysis. Section 5 summarises our data while Section 6 presents our results of FDI aggregation using spatial empirical methods. Section 7 concludes.

2. AGGREGATION OVER INTEGRATION STRATEGIES AND SPACE

Central to the recent wave of globalisation is the ever-evolving MNCs with their numerous and rather diverse integration strategies. The world has witnessed an unprecedented expansion of FDI in the recent two decades. Sales of foreign affiliates of MNCs around the globe have quintupled from 1990 to 2012 reaching 26 trillion dollars. While these sales constituted 23 per cent of world GDP in 1990, this share has jumped to 36 per cent in 2012 (United Nations Conference on Trade and Development, 2013).

It proved convenient in the theory of trade and multinational firms to divide FDI conducted by MNCs into three groups: horizontal and vertical FDI in the early years and then recently complex or hybrid FDI.

The theories of horizontal and vertical FDI are now standard in the FDI literature and need no extended discussion here. Horizontally integrated MNCs serve foreign markets locally rather than by exporting to save on trade costs, whereas vertically integrated MNCs arise from international differences in factor endowments when stages of production differ in their factor intensities.

Many of the present-day MNCs, however, are neither horizontal nor vertical. Instead, an affiliate may be set up to serve as an export platform to nearby countries with low trade costs or due to agglomeration incentives such as supplier networks and location of immobile resources. Different from earlier FDI models, complex FDI theories include at least three countries with a plethora of integration strategies across boundaries. These rich structures with complex third-country effects point to spatial interdependencies in FDI activity.

Among the theoretical studies addressing the complex nature of FDI are Motta and Norman (1996), Neary (2002), Yeaple (2003), Grossman et al. (2006) and Ekholm et al. (2007). In this class of models, usually two countries form a trading bloc lowering the intrabloc trade costs. External trade barriers remain more or less the same as before. One generic result of these models is that intrabloc trade liberalisation encourages horizontal FDI in trading blocs since foreign firms can use one of the member countries as an export platform to serve the entire region.

Empirical work that includes these types of third-country effects was limited until recently. Seminal papers by Head et al. (1999) and Head and Mayer (2004) focus mostly on agglomeration effects and analyse the determinants of location choices by Japanese firms in Europe. Inspired by the new economic geography literature, in the latter paper they include a market potential variable

[2] In 1998, exports to Sweden constituted roughly 8 per cent of affiliate sales. The remainder 92 per cent was sold to the local market or exported to third countries. This is roughly in line with the findings of Ekholm et al. (2007) who report that, in 2013, US affiliates exported 13 per cent of their sales back to the United States, while they exported 26 per cent of sales to third countries.

that includes not only the market size of the FDI host but also the distance-weighted GDP of other locations. Their results indicate that Japanese FDI in Europe is encouraged by market potential, which can be interpreted as evidence for agglomeration effects.

However, to test for the relevance of third-country effects, a more systematic treatment of spatial interdependencies with more flexibility is needed. In this matter, spatial econometrics has been used recently to improve our understanding of FDI patterns. An early paper by Coughlin and Segev (2000) applies spatial techniques to allow for interdependence of inbound FDI activity into 29 Chinese provinces. Using statistical tests on OLS to choose between the spatial error and the spatial lag model, they find support for spatial error model and present evidence of positive spatial autocorrelation.

Relying on existing complex FDI theory, Blonigen et al. (2007) estimate the so-called spatial lag specification to analyse US outbound FDI from 1983 through 1998. Their analysis shows evidence for export-platform FDI in the developed European countries. However, the estimated spatial interdependence remains sample (OECD sample versus European sample) and scale (country versus industry-level data) sensitive.

Concurrently, Baltagi et al. (2007) using panel data on US outbound FDI over the 1989–99 period estimate a 'complex FDI' model by allowing for spatially lagged independent variables and the spatial error. They find significant third-country effects. In a related paper, Baltagi et al. (2008) investigate the impact of trade liberalisation on FDI using a sample of 28 host countries over the period 1989–2001. Their results suggest that elimination of tariff barriers not only affects FDI going into the involved parties but also the other host countries. Using spatial econometrics, Garretsen and Peeters (2009) also find that for Dutch FDI to 18 host countries, third-country effects matter. In a study comparing the spatial autoregressive method to the matrix exponential spatial specification, Debarsy et al. (2015) estimate Belgium's outward FDI into 35 countries in 2009 finding significant spatial spillovers using both methods. All these papers, in essence, test for a 'spacey-host hypothesis' where FDI into proximate countries is interdependent. This interdependency could arise from lower trade costs, supplier networks or geographic concentration of immobile resources in proximate countries (Blonigen et al., 2007).

Another test for a 'spacey-host hypothesis' is provided by Basile et al. (2013) using data on 1,930 greenfield investment projects in 249 European regions over the 2003–07 period. They estimate a semi-parametric spatial autoregressive negative binomial model to address two important methodological issues: spatial dependence and non-linearities. This study also reports strong third-country effects even after controlling for a large number of regional characteristics. Note, however, that their study estimates the count of new greenfield investment projects within a country and does not employ any firm-level detail.

Interdependency of the location and output decisions of MNCs from different parent countries in a given host country, on the other hand, is called 'spacey-parent hypothesis'. This hypothesis could be driven by competition for scarce resources in the host country that are lacking in proximate parent countries or positive production externalities across headquarters in proximate parent countries (Blonigen et al., 2008). Blonigen et al. (2008) illustrate that when US inbound FDI from OECD countries over the period 1980–2000 is considered, the United States receives more FDI from parent countries that are geographically closer to large third-country markets. Badinger and Egger (2009) formulate an integrated spatial econometric panel data model to test for the two hypotheses simultaneously. Using OECD data from 1995 to 2004, they come to conclusion that spaceyness matters for both parents and hosts.

More recently Badinger and Egger (2013) introduce a 'spacey-third-country hypothesis' by arguing that the general equilibrium effects lead FDI for a given parent–host country pair to be interdependent with FDI between other pairs. Using a cross section of country pairs for 22 OECD countries in year 2000, they find evidence for all three spacey hypotheses.

Without exception, all these studies are conducted using aggregate country or country-pair level data even though the FDI theory that they are based on is at the firm level. There is just one recent exception – Chen (2010), who finds evidence that spatial interdependencies matter at the affiliate level as well. Chen (2010) examines the effect of existing production networks on MNCs' entry decisions using French multinationals' affiliate data for years 2005 and 2007. The data set includes the affiliate's location, primary product, sales, assets and employment. She reports strong evidence of horizontal and vertical interaction between MNCs' foreign production locations. Surprisingly though she finds little support for horizontal interdependence between multinationals' production at home and new investments abroad once the third-country effects are taken into consideration suggesting a lack of evidence for tariff-jumping FDI. Chen is the first to use affiliate-level variation in estimating the spatial lag coefficient in FDI decisions, but her data lend itself to only analysing location choice (the extensive margin). We in contrast determine the spatial interdependencies in affiliates' level of sales activity (the intensive margin).

As discussed above, existing empirical analyses of FDI largely suffer from the ecological fallacy because firm-level theories are tested using country-level data. The scale problem of the MAUP is likely present in many empirical FDI studies conducted using aggregated data. Shedding light on this scale problem can contribute to our understanding of results produced by this literature. Therefore, in this paper, our objective is to investigate the aggregation issues in FDI estimation using the horizontal, vertical and complex FDI distinction as the backdrop. Next, we provide a simple theoretical model to illustrate how aggregation bias may arise.

3. AGGREGATING FROM THE AFFILIATE TO THE FIRM–COUNTRY LEVEL: A SIMPLE MODEL

As we will document below, Swedish MNCs frequently have more than one affiliate in a single host country, with affiliates producing multiple products.[3] This section presents a very simple model of market-seeking platform FDI to illustrate how aggregation bias may occur in estimations when aggregating from the affiliate to the firm–host country level.

Consider a single MNC producing four varieties of a final good of which it is the single producer.[4] The MNC produces each variety in a single affiliate. To highlight the effects of within-firm aggregation of affiliates over host countries on spatial correlation, we take location as given and assume that two affiliates – affiliate 1 and affiliate 2 – are located in host country A, whereas affiliates 3 and 4 are located in host country B. There is also country C to which all affiliates export. Markets are segmented.

[3] This is hard to reconcile with standard proximity-versus-scale trade-off models (Horstmann and Markusen, 1992; Brainard, 1997; Helpman et al., 2004), since firms typically produce a single product which is sold to foreign markets either by exports or from production in a single affiliate in the host country.

[4] This set-up follows Baldwin and Ottaviano (2001).

Let us illustrate how aggregation bias arise using affiliate exports to country C (third-country exports).[5] Consumers have the following identical preferences (Singh and Vives, 1984):

$$u = \sum_{i=1}^{4} aq_i - \frac{1}{2}\left[\sum_{i=1}^{4} q_i^2 + \beta \sum_{i=1}^{4}\sum_{j\neq i}^{4} q_i q_j\right], \tag{1}$$

where $a > 0$ and $\beta \in (0,1)$ is the (inverse) degree of product differentiation and q_i represents the output from affiliate i.

It follows that the inverse demand for good i is:

$$p_i = a - q_i - \beta \sum_{j\neq i}^{4} q_j, \quad i = \{1,2,3,4\}. \tag{2}$$

The total profit of the MNC is the aggregate profit from the sales of all of its affiliates:

$$\pi = \sum_{i=1}^{4} [p_i - c_i] q_i, \tag{3}$$

where c_i is the marginal cost (including trade costs) faced by affiliate i. The MNC chooses the output of each affiliate to maximise its total profit in (3), subject to the inverse demand for the different varieties in (2). This gives the first-order condition $(\partial\Pi/\partial q_i) = 0$, or:

$$p_i - q_i - \beta \sum_{j\neq i}^{4} q_j - c_i = 0, \quad i = \{1,2,3,4\}. \tag{4}$$

The first two terms in (4) represent the ‘standard’ marginal revenue effect: selling one more unit of brand i increases revenues by the price of good i, but the additional unit also reduces the price on the market, affecting all previous sales. The third term shows the so-called cannibalisation effect on the firm’s other varieties where the impact on their price from an additional unit of sales of good i is given by the product differentiation parameter β. The fourth term is affiliate i’s marginal cost.

It is instructive to rewrite (4) in a ‘best-response’ form. Using (2) and solving for the optimal exports of affiliate i as a function of the exports of the other brands, or varieties, and defining $\Lambda_i = a - c_i$, we get:

$$q_i = \frac{1}{2}\Lambda_i - \beta \sum_{j\neq i}^{4} q_j, \quad i = \{1,2,3,4\}. \tag{5}$$

We can now rewrite (5) into the form of a spatial regression equation, $\mathbf{q} = \alpha + \rho^{Aff}\boldsymbol{W}'\,\mathbf{q}$, or:[6]

[5] Affiliates 1 and 2 in the market of country A compete with each other as well as with the imports from the country B affiliates. Likewise, affiliates 3 and 4 in country B compete with each other and with import sales from the two country A affiliates in country B. Aggregation bias will also emerge in these markets.

[6] For simplicity, we omit the error terms.

$$\begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \end{bmatrix} = \begin{bmatrix} \frac{1}{2}\Lambda_1 \\ \frac{1}{2}\Lambda_2 \\ \frac{1}{2}\Lambda_3 \\ \frac{1}{2}\Lambda_4 \end{bmatrix} - 3\beta \begin{bmatrix} 0 & 1/3 & 1/3 & 1/3 \\ 1/3 & 0 & 1/3 & 1/3 \\ 1/3 & 1/3 & 0 & 1/3 \\ 1/3 & 1/3 & 1/3 & 0 \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \end{bmatrix}, \tag{6}$$

where we have row-standardised the weighting matrix $\boldsymbol{W}$. Note that the spatial coefficient in this affiliate-level regression equation is $\rho^{Aff} = 3\beta$. What if we now aggregate the data so that we instead examine the spatial relationship between the sum of exports from country A produced by affiliates 1 and 2, $Q_{12} = q_1 + q_2$, and the sum of exports from country B, produced by affiliates 3 and 4, $Q_{34} = q_3 + q_4$? We can do this by summing the best-response functions in (5) for affiliates 1 and 2, and then summing the ones for affiliates 3 and 4, finally solving for the aggregate reaction functions. This generates a corresponding firm–country level spatial regression equation $Q = \alpha + \rho^{Firm} W' Q$, or:

$$\begin{bmatrix} Q_{12} \\ Q_{34} \end{bmatrix} = \begin{bmatrix} \frac{\Lambda_1+\Lambda_2}{2(1+\beta)} \\ \frac{\Lambda_3+\Lambda_4}{2(1+\beta)} \end{bmatrix} - \frac{2\beta}{1+\beta} \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} Q_{12} \\ Q_{34} \end{bmatrix}, \tag{7}$$

where we, again, have row-standardised the weighting matrix $\boldsymbol{W}$.

Note that the spatial coefficient in this firm–country level regression is $\rho^{Firm} = 2\beta/(1+\beta)$. Clearly, from (6) and (7) the spatial coefficient in the affiliate-level regression equation is higher than in the corresponding firm-country regression equation; that is, there is an aggregation bias:

$$\rho^{Bias} = \rho^{Aff} - \rho^{Firm} = \beta \frac{3\beta + 1}{\beta + 1} > 0, \quad \text{since } \beta \in (0, 1). \tag{8}$$

What is the intuition behind the aggregation bias $\rho^{Bias} > 0$? When we aggregate the best-response functions in (5) over each affiliate in countries A and B (where the production takes place in this example), we lose valuable information. In particular, we lose the information that affiliates 1 and 2 are competing with each other; likewise, affiliates 3 and 4 are competing with each other. By aggregating over affiliates and using a different scale in our estimations, we overlook the competition between the affiliates of a multiproduct multinational and therefore obtain a weaker spatial correlation.

In the above described model, competition between affiliates within the same firm is crucial to explain the aggregation bias. We capture this competition through product differentiation following Baldwin and Ottaviano (2001). Intrafirm competition can also be introduced in other ways. Yeaple (2013), for instance, shows that if organisational capital is scarce, then a rivalry between affiliates will also be created.[7]

4. EMPIRICAL MODEL

It is likely that FDI from Sweden is driven by a combination of motivations: vertical, horizontal or other. The strength of our paper is that we have very detailed affiliate-level sales data that allow us to study the presence of different types of FDI activity at

[7] More generally, if incentives problems arise with managers, firms may use intrafirm competition to restrain managers from opportunistic behaviour.

different aggregation levels using a spatial framework. This way we are able to observe whether inferences about the sales activity change when the spatial scale of the observation changes.

While most affiliates choose to sell at local markets in the host country (97 per cent), a large proportion of affiliates do not export to third countries (30 per cent) or back to Sweden (53 per cent). Affiliate and firm-level sales data are therefore zero-inflated.[8] Following Diao (2015), to control for this selection problem we integrate the Heckman (1979) selection correction procedure for zero-inflation with the spatial regression models.[9] In the first step of the Heckman procedure, we estimate the probability that an affiliate engages in a particular type of sales ($Y_{it} > 0$) as follows:

$$Pr[Y_{it} > 0] = \Phi[\theta z_{it} + \sigma_t],$$

where Φ is the standard normal cumulative distribution function. z_{it} include the independent variables from the main estimation equation discussed below (*Market Potential* and other controls X) as well as distance from Sweden and industry dummies allocating each affiliate into one of five broad categories according to a taxonomy in OECD (1987, 1992): resource intensive, labour intensive, scale intensive, differentiated goods and science-based goods. Distance and industry categories are excluded from second stage of the regression due to included firm and country-fixed effects. σ_t is year-fixed effects. Based on the estimated coefficients from the Probit equation above, an inverse Mills ratio (*Mills*) is computed as:

$$Mills_{it} = \frac{\phi\left[\hat{\theta} z_{it} + \hat{\sigma}_t\right]}{\Phi\left[\hat{\theta} z_{it} + \hat{\sigma}_t\right]},$$

where ϕ is the standard normal density function. The inverse Mills ratio is then included as an independent variable in our spatial regression models estimating the level of sales. Next, we discuss the spatial mixed model that allows for a spatial lag and a spatial error term to control for both spatial autoregression and spatial autocorrelation, respectively.[10]

a. Affiliate-level Model

We begin our estimation with the panel model estimating sales activity (Y) of affiliate i of firm f in country c in year t:

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[8] Note that we only examine sales flows in existing affiliates, that is, we do not examine the so-called extensive margin or the decision to establish a new affiliate. Such an analysis is involved at the affiliate level. Suppose that a firm has existing affiliates in several host countries. We would then need to predict the firm's choice between investing into one or several additional affiliates in a host country, or doing this in other existing or new host countries. This would generate a huge number of available investment alternatives. Most studies, therefore, examine the extensive margin by simply looking at the single decision of a firm to invest or not invest into a host country (Norbäck, 2001).

[9] Cameron and Trivedi (2009, p. 633) state that 'in many applications where a tobit model is used, a more general sample-selection model may be warranted'. Recent theoretical work by Qu and Lee (2012, 2013) and Xu and Lee (2015) analyses the cross-sectional spatial tobit model. Even in their cross-sectional setting, these authors restrict their model to just the spatial lag model and ignore the spatial error.

[10] The spatial econometric models are discussed in Anselin (1988) and LeSage and Pace (2009). We use Jeanty's (2013) Stata code *spmlreg* to run our regressions.

$$Y_{i,f,c,t} = \rho Spatial\,Lag_{i,f,c,t} + \delta Ln(Market\,Potential_{c,t}) + \beta X_{i,f,c,t} + \upsilon Mills_{i,f,c,t} + \alpha_f + \kappa_c + \gamma_t + u_{i,f,c,t},$$

where we allow for a non-zero spatial error coefficient (λ):

$$u_{i,f,c,t} = \lambda \sum_{j \neq i} \omega_{cd} u_{j,f,d,t} + \varepsilon_{i,f,c,t},$$

and where the spatial lag is the distance-weighted average of the firm's other affiliates' Y-values in other countries:

$$Spatial\,Lag_{i,f,c,t} = \boldsymbol{W}_s * Y = \sum_{j \neq i} \omega_{cd} Y_{j,f,d,t}.$$

The weight, ω_{cd}, is the weight from a row-standardised matrix $\boldsymbol{W}_s$ that rescales the matrix $\boldsymbol{W}$ below so that the weights of each row add to one:

$$\boldsymbol{W} = \begin{bmatrix} \boldsymbol{W}_{1965} & 0 & 0 \\ 0 & \ldots & 0 \\ 0 & 0 & \boldsymbol{W}_{1998} \end{bmatrix}.$$

The matrix $\boldsymbol{W}$ is made up of year-specific matrices on the diagonal and zeros in the off-diagonal blocks. Each year-specific diagonal is further made up of firm-specific matrices as follows:

$$\boldsymbol{W}_{1998} = \begin{bmatrix} \boldsymbol{W}_1 & 0 & 0 \\ 0 & \ldots & 0 \\ 0 & 0 & \boldsymbol{W}_{43} \end{bmatrix}.$$

The blocks in matrix $\boldsymbol{W}_{1998}$ correspond to a particular firm with affiliates in more than one country. In our affiliate-level regression samples, there are 43 such firms for 1998. The firm-specific diagonal blocks are constructed based on distances between different affiliates' countries. For example, if firm f operates three affiliates in countries c, d and e, then its block would be constructed as follows:

$$\boldsymbol{W}_f = \begin{bmatrix} 0 & dist_{cd}^{-2} & dist_{ce}^{-2} \\ dist_{cd}^{-2} & 0 & dist_{de}^{-2} \\ dist_{ce}^{-2} & dist_{de}^{-2} & 0 \end{bmatrix},$$

where $dist$ is the distance between the capital cities of country c and country d and baseline weight function is inverse distance squared.[11] Affiliates within the same country obtain within-country distance provided by our data source, CEPII. The diagonal values of the weighting matrix always equal zero to give no weight to the affiliate's own sales activity.

The size of the spatial lag coefficient, ρ, represents the strength of spatial spillovers in affiliate sales. In our study, we will focus on the size and sign of spatial lag coefficient. We are primarily interested in how affiliate activities are related across space and how this relationship depends on the way the researcher aggregates the data. With this focus, we will not estimate the full effect of X_{ki} on all observations of Y, but rather only report the effect of X_{ki} on Y_i. Following Kim et al. (2003), Small and Steimetz (2012) and Woodard et al. (2012), we

[11] An alternative weighting scheme for constructing the weighting matrices was used as a robustness check, $\omega_{ij} = e^{-dist/1,000}$. The main results were qualitatively unchanged.

then define direct effects of X_{ki} on Y_i as β_k and indirect effects as the spillovers to other affiliates and then back to affiliate *i*. To obtain the total effect of X_{ki} on Y_i, we use $1/(1-\rho)\beta_k$, a result derived by Kim et al. (2003). While it would be interesting to explore this issue further, we should note that the way in which one calculates the effect of the non-spatial covariates has no impact on the size and sign of the spatial lag coefficient, ρ, which is our central interest here.

The second spatial variable we consider is the market potential of a country, denoted by *Ln (Market Potential)*. This variable helps determine whether surrounding markets contribute to firms' FDI activity. *Market Potential* is calculated for each country as the inverse distance-weighted sum of other countries' GDPs. The estimated coefficients for *Spatial Lag* and *Market Potential* will be key in determining the models of FDI that best explain Swedish MNC affiliate behaviour. *Spatial Lag* could take on positive or negative values, whereas *Market Potential* coefficient is expected to be either zero or positive, depending on the FDI motivation.

Covariates in *X* include affiliate, firm and host-country characteristics. The affiliate-level variables include a dummy identifying sales affiliates (*Sales Affiliate*), age of the affiliate (*Age*) and an experience dummy (*Experience*) that takes on the value one if the firm had previous experience in that country and zero otherwise.

Firm characteristics include the size of the firm (*Firm Size*) measured by the sales of the whole MNC and the R&D intensity of the parent firm (*R&D*) to proxy for firm-specific assets. R&D intensity is measured by R&D expenditure as a share of total sales.

The host-country characteristics come from the standard gravity framework and include real GDP (*GDP*) to control for the size of the market, GDP *per capita* (*GDP/Pop*) to control for the wealth of the country, openness of the country (*Open*) to control for trade costs and trade bloc dummies for the *EU*, *NAFTA* and *ASEAN*. GDP, GDP *per capita* and openness (measured by imports plus exports divided by GDP) come from Penn World Tables (Summers and Heston, 1991). Other control variables are a dummy *Treaty,* which is equal to one if there is an effective tax treaty between Sweden and the host country and *Tax Rate,* which is the highest tax bracket of corporate income tax in the host country. Both variables are reported in the World Tax Database of the Office of Tax Policy Research in University of Michigan.

The distance variable ($Distance_{SWE}$) from the CEPII database online is included in the first stage of the Heckman model to calculate the inverse Mills ratio.[12] The inverse Mills ratio (*Mills*) discussed above is included to control for sample selection. Home country variables have been excluded because all the firms considered by this study come from Sweden. Finally, we include α_f, κ_c and γ_t to control for firm, country and year-fixed effects. $\varepsilon_{i,f,c,t}$ is the i.i.d. random error. Table 1 provides the summary statistics for all data used in the affiliate-level regressions.

b. The Expected Impacts of Rival Motivations for FDI

Two dominant FDI theories driven by access to markets are horizontal FDI and export-platform FDI theory. To test for the presence of these theories, we employ data on the local sales of the affiliate and exports to third countries. Rival motivations for FDI are driven by

[12] Distance variable is also included in regressions without country fixed effects discussed briefly below and available upon request.

TABLE 1
Affiliate-level Descriptive Statistics

Variable	*Observations*	*Mean*	*SD*	*Min*	*Max*
Ln(Exports to Third)	2,953	2.22	2.13	0	9.26
Exports to Third	2,953	100.97	446.38	0	10.51
Ln(Local Sales)	2,659	3.77	1.78	−4.14	9.87
Local Sales	2,659	202.56	761.86	−0.98	19331.38
Ln(Exports to Sweden)	2,966	0.94	1.42	0	9.96
Exports to Sweden	2,966	29.53	559.34	0	21.10
Ln(Market Potential)	2,966	8.71	0.68	6.40	9.90
Market Potential	2,966	7376.61	4081.37	599.54	19841.31
Age	2,966	14.16	16.39	0	103
Ln(Firm Size)	2,966	8.85	1.93	2.47	12.31
Firm Size	2,966	25607.88	38007.89	11.77	223004.80
Ln(R&D)	2,966	−4.20	1.27	−9.21	−1.76
R&D	2,966	0.03	0.03	0.00	0.17
Tax Rate	2,966	38.16	9.76	3	80
Ln(GDP)	2,966	20.10	1.43	15.48	22.85
GDP	2,966	1.34E+09	1.98E+09	5.29E+06	8.41E+09
Ln(GDP/Pop)	2,966	9.63	0.57	6.61	10.34
GDP/Pop	2,966	16984.84	6423.10	746.10	31090.66
Ln(Open)	2,966	3.71	0.58	2.21	5.82
Open	2,966	48.06	30.18	9.12	336.51
Ln(DistanceSWE)	2,966	7.60	1.02	5.93	9.78
DistanceSWE	2,966	3389.16	3691.70	377.94	17738.59
Sales Affiliate	2,966	0.14			
Experience	2,966	0.96			
Treaty	2,966	0.94			
EU	2,966	0.53			
NAFTA	2,966	0.09			
ASEAN	2,966	0.01			

Notes:
(i) Data were collected for years 1965, 1970, 1974, 1978, 1986, 1990, 1994 and 1998.
(ii) Units for the linear forms of the variables are as follows: (1) *Exports to Third*, (2) *Local Sales* and (3) *Exports to Sweden* are measured in millions Swedish kronor. (4) *Market Potential* is the weighted sum of other countries GDP. (5) *Firm Size* is measured in million Swedish kronor. (6) *R&D* is R&D expenditures divided by firm sales. (7) *GDP* in 1,000 US$. (8) *GDP/Pop* in US$. (9) *Open* measures trade intensity of an economy and is calculated exports plus imports divided by GDP. (10) *Distance* is measured in kilometres.

access to cheaper inputs, and we test for those using affiliate exports back to Sweden. The dominant theory related to these exports is the pure vertical theory of FDI.

To distinguish between alternate motivations of FDI, we focus on two spatial variables. The first is the spatial lag variable or the spatial autoregressive variable that is the weighted sum of other affiliates' FDI. As discussed below, the spatial lag coefficient could be either positive or negative depending on the dominant type of FDI. The second key spatial variable is market potential of a country. Depending on the type of FDI motivation, we expect *Market Potential* either to be positive or to not matter.

We would expect third-country exports to be explained by export-platform theory for affiliates. Here, market potential of a country should attract more FDI and the spatial lag is expected to be negative. That means export-platform FDI is a substitute in space – the more an affiliate in one country exports to third countries the less the nearby countries' affiliates export.[13] The contribution of our work is to determine whether aggregation bias resulting from the scale problem of MAUP is serious in these data.

Local sales, if driven by pure horizontal theory, should not be affected by nearby countries' characteristics; that is, *Spatial Lag* and *Market Potential* are expected to be insignificant. It is likely, though, that exports to third countries are related to local sales. When a firm sets up an affiliate to serve a foreign market, it is also likely to use this affiliate to serve other nearby countries through third-country exports.

Exports back to Sweden, at least in theory, are driven by very different motivations. Here, pure vertical theory should be the dominant one to explain exports back to home country. If an affiliate is set up to source inputs, then neighbouring countries with similar characteristics are likely to see less vertical FDI activity by the firm.

However, when MNEs locate different activities along the value chain to take advantage of different host country characteristics, exports back to Sweden may be associated with a positive spatial lag (for instance, when such exports reflect inputs used in final production in Sweden). This would be supported by a competing theory of FDI that posits strong agglomeration effects that dominate the other FDI motives. If agglomeration and network effects are strong enough for any of the three variables under consideration, we are also likely to find a positive spatial lag coefficient. Blonigen et al. (2007) called this type of FDI motivation vertical specialisation with agglomeration.

c. Firm-level Model

Next, to analyse the effects of aggregation, data are aggregated from affiliate to firm level within each country. The firm-level empirical models estimate sales of firm f in country c in year t as follows:

$$Y_{f,c,t} = \rho Spatial\,Lag_{f,c,t} + \delta Ln(Market\,Potential_{c,t}) + \beta X_{f,c,t} + \upsilon Mills_{f,c,t} + \kappa_c + \gamma_t + u_{f,c,t},$$

where we allow for a non-zero spatial error term:

$$u_{f,c,t} = \lambda \sum_{k \neq f} \omega_{cd} u_{k,d,t} + \varepsilon_{f,c,t},$$

and where the spatial lag is the distance-weighted average of the firm's sales in other countries:

$$Spatial\,Lag_{f,c,t} = \boldsymbol{W}_s * Y = \sum_{k \neq f} \omega_{cd} Y_{k,d,t}.$$

In all of our analysis, the weights are based on row-standardised matrices for which initial weights are $1/distance^2_{cd}$ as discussed above. The firm-level aggregation would be appropriate if the affiliates are vertically integrated within a country.

d. Country-level Model

To further determine whether aggregation bias is present, data are finally aggregated to country level. The aggregate country-level models estimate Swedish MNC sales activity (Y) in country c in year t as follows:

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[13] The model in Section 3 derives a negative spatial lag for affiliate exports to third markets.

$$Y_{c,t} = \rho Spatial\,Lag_{c,t} + \delta Ln(Market\,Potential_{c,t}) + \beta X_{c,t} + \kappa_c + \gamma_t + u_{c,t},$$

where:

$$u_{c,t} = \lambda \sum_{c \neq d} \omega_{cd} u_{d,t} + \varepsilon_{c,t},$$

and

$$Spatial\,Lag_{c,t} = \boldsymbol{W}_s Y = \sum_{c \neq d} \omega_{cd} Y_{d,t}.$$

The weight, ω_{cd}, is from a row-standardised matrix W_s. We get W_s by scaling each row of the following block-diagonal matrix $\boldsymbol{W}$ so that the rows add to one:

$$W = \begin{bmatrix} \boldsymbol{W}_{1965} & 0 & 0 \\ 0 & \ldots & 0 \\ 0 & 0 & \boldsymbol{W}_{1998} \end{bmatrix}.$$

Each block in matrix $\boldsymbol{W}$ corresponds to a particular year, t. Our data span eight survey years between 1965 and 1998, which means the matrix $\boldsymbol{W}$ contains eight blocks, $\boldsymbol{W}_t$. The year-specific diagonal blocks are constructed based on distances between different countries. For example, in 1998 affiliates of Swedish MNCs sold to 45 countries, which means the block $\boldsymbol{W}_{1998}$ is a 45 by 45 symmetric matrix. To illustrate the construction of these matrices suppose that in year 1998 Sweden invested in three countries – c, d and e. Then, the block $\boldsymbol{W}_{1998}$ would be made up of inverse distance squared of distances between these three countries with zeroes on the diagonals:

$$\boldsymbol{W}_{1998} = \begin{bmatrix} 0 & dist_{cd}^{-2} & dist_{ce}^{-2} \\ dist_{cd}^{-2} & 0 & dist_{de}^{-2} \\ dist_{ce}^{-2} & dist_{de}^{-2} & 0 \end{bmatrix}.$$

Additional covariates, $X_{c,t}$, are the same host-country variables we included in the affiliate-level regressions.

5. AFFILIATE AND FIRM-LEVEL DATA

The Research Institute of Industrial Economics (RIIE), the source of our primary data, has conducted eight surveys of the foreign activities of Swedish Multinational firms in the years 1965, 1970, 1974, 1978, 1986, 1990, 1994 and 1998.[14] The purpose of these surveys has been to study all Swedish firms meeting the following criteria: (i) the firm's main activity should be within the manufacturing sector; (ii) the total number of employees should be at least 50; (iii) the firm should have at least one producing affiliate abroad and (iv) the domicile should be located in Sweden.

The information on the coverage of the surveys is summarised in Table 2, which reviews the number of firms and affiliates taking part of the survey. As easily observed, there is a

[14] See Swedenborg (1979) for an early study using the data. There was also a survey in 2003; however, given the considerable fall in the answering rate, we only use the data from 1965 to 1998. For details see http://www.ifn.se/eng/research/databases_10/foreign_operations_of_swedish_manufacturing_firms. This website presents the surveys in more detail and lists books and published papers using the data.

TABLE 2
Description of the Research Institute of Industrial Economics Surveys

Year	*Participating Firms*	*Answering Rate (%)*	*Participating Affiliates*	*Answering Rate (%)*	*Total Affiliate Employment*
1965	108	95	328	82	147,292
1970	108	95	418	100	182,087
1974	108	95	480	100	221,111
1978	122	93	567	100	227,149
1986	108	95	646	99	259,823
1990	120	NA	871	91	440,879
1994	132	86	689	97	531,994
1998	118	77	703	71	223,061

very high answering rate both among firms and their affiliates. Although the decline in 1998 is noteworthy, the answering rate is still high, almost 80 per cent. In the earlier surveys about 70 per cent of the firms remain in two consecutive surveys, whereas in the later surveys, only about half of the firms remain in the sample in two consecutive surveys. This may reflect the decline in answering rate but also mirrors that in the 1990s, regulations against foreign acquisitions of Swedish firms were lifted. A number of large Swedish MNCs such as Pharmacia, Astra, Volvo and SAAB were also acquired by or merged with non-Swedish firms.

Swedish multinationals dominate Swedish manufacturing activity. In 1990, MNCs accounted for more than 50 per cent of Swedish exports, about 25 per cent of Swedish total manufacturing employment and roughly 90 per cent of R&D expenditures (Svensson, 1996). The importance of their foreign activities has increased. Over time, overseas employment by Swedish MNCs as a share of total employment increased from slightly above 30 per cent in 1965 to almost 70 per cent in 1998.

As shown in Table 3, in 1998 about one of five foreign workers in Swedish MNCs had their employment in an affiliate in the United States. Other important locations for foreign employment were the large Western European countries: Germany, France, Italy and the UK. The share of employment in the European countries remained fairly stable over time, whereas the importance of the US market has increased. These investments are likely to be driven by market-seeking (horizontal) FDI.

Developed countries attract the bulk of investments, a pattern not unique for Swedish multinationals. On the developing countries side, Swedish firms have traditionally had significant investments in Latin America, in particular Brazil, in response to import-substituting policies.

In the 1990s, there is evidence of cost-driven (vertical) FDI growing in importance, and affiliate employment emerging in the Eastern European countries such as Estonia, Hungary and Poland. In these years, Swedish firms also increased investments in China. There is a large percentage increase in both the number of firms and the number of affiliates in almost every host over time.

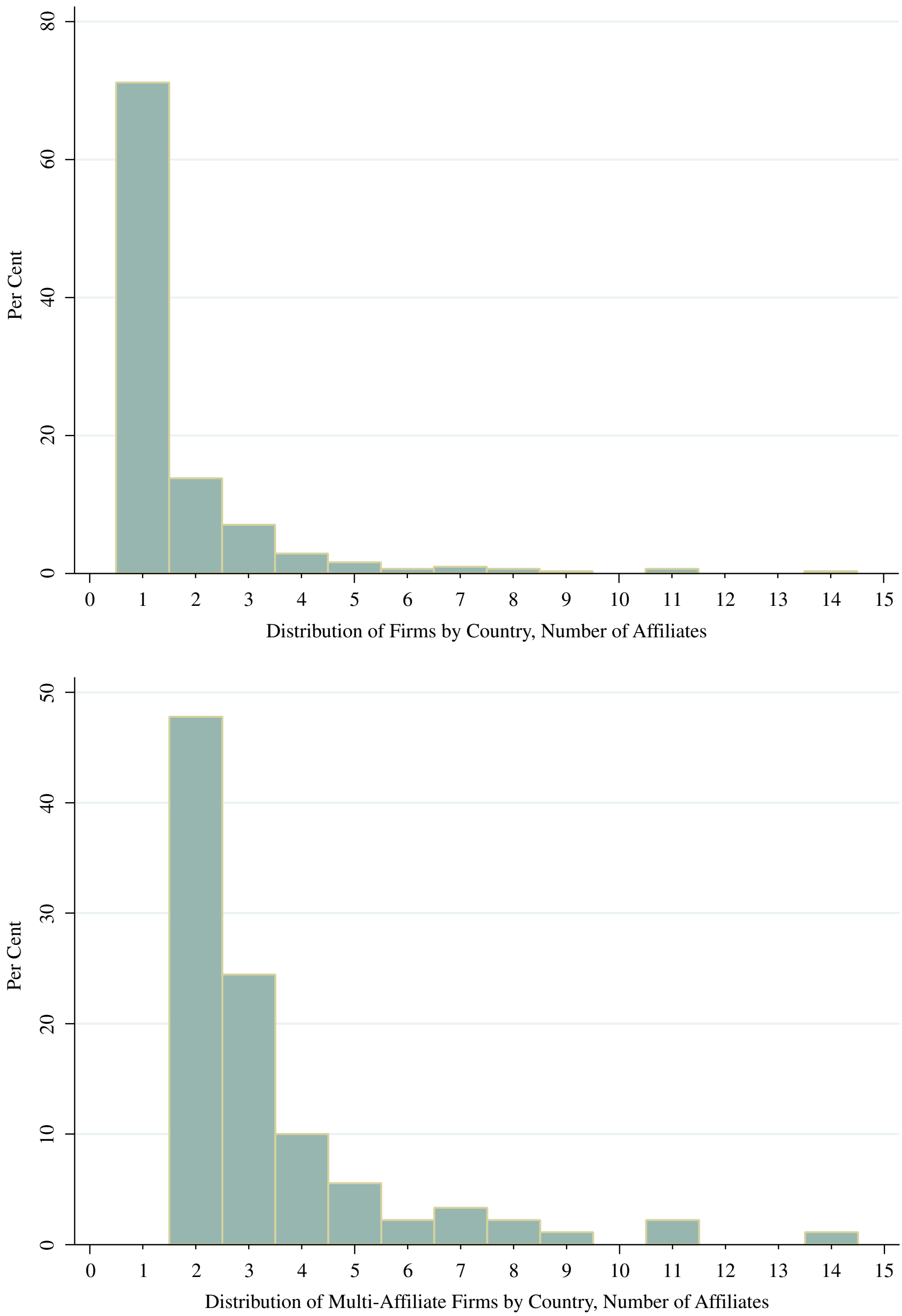
Figure 1 shows the affiliate structure of the Swedish firms in 1994. The upper diagram is a histogram of the total number of foreign affiliates owned by Swedish firms in a given country in 1994. About 70 per cent of affiliates are the sole affiliate of its Swedish parent within the host country. The remaining 30 per cent of affiliates share the host country with one or more

TABLE 3
Number of Firms, Number of Affiliates and Employment by Host Country, 1998

Rank	*Country*	*No. Firms Active in 1998*	*No. Aff. Active in 1998*	*Total Aff. Emp. in 1998*	*Rank*	*Country*	*No. Firms Active in 1998*	*No. Aff. Active in 1998*	*Total Aff. Emp. in 1998*
1	United States	16	60	39,998	24	Czech Republic	[a]	[a]	708
2	Germany	19	52	19,935	25	Sri Lanka	[a]	[a]	678
3	Brazil	9	14	9,931	26	Japan	4	5	626
4	UK	19	37	9,486	27	Slovak Republic	[a]	[a]	484
5	France	12	28	7,934	28	Russian Federation	3	3	450
6	Canada	6	13	7,413	29	Thailand	[a]	[a]	450
7	Denmark	16	23	5,159	30	Malaysia	[a]	[a]	332
8	Belgium	13	15	4,533	31	Ireland	[a]	[a]	311
9	Spain	6	13	4,066	32	The Netherlands	11	16	281
10	Mexico	5	7	3,943	33	Estonia	3	4	255
11	Finland	15	24	3,217	34	Greece	[a]	[a]	238
12	Hungary	4	8	3,152	35	Poland	13	15	224
13	India	6	10	3,029	36	Italy	11	36	159
14	China	7	12	2,537	37	Peru	[a]	[a]	158
15	Romania	[a]	[a]	1,829	38	Indonesia	[a]	[a]	75
16	Austria	5	5	1,624	39	Turkey	[a]	[a]	57
17	Argentina	[a]	[a]	1,516	40	Zimbabwe	[a]	[a]	55
18	Norway	9	12	1,449	41	Latvia	[a]	[a]	40
19	Australia	4	7	1,154	42	Colombia	[a]	[a]	32
20	Switzerland	5	6	1,047	43	Lithuania	[a]	[a]	26
21	Korea, Republic	[a]	3	900	44	Kenya	[a]	[a]	13
22	Portugal	3	3	814	45	Zambia	[a]	[a]	4
23	South Africa	[a]	3	755					
					Number of affiliates/employed			459	161,36

Note:
[a] Information suppressed when there are less than three firms due to confidentiality reasons.

FIGURE 1
Number of Swedish Affiliates by Firm and Country in 1994



affiliate of the same parent. The number of multiple affiliates in a host country reaches up to 14 affiliates. Not only do these firms operate multiple affiliates but also they frequently are in the same industry. For instance, in the year 1994, one particular firm producing hygiene products, pulp, paper, sawn wood and pellets, produced in five different product codes in 47 affiliates and was active in 13 countries. In many cases, a Swedish firm was active with multiple affiliates within the same sector in the same country.

The lower diagram of Figure 1 concentrates on the multi-affiliate Swedish multinationals and presents a new histogram for these firms. Among these multi-affiliate firms (30 per cent of the sample), there is considerable amount of heterogeneity. About half of them have two affiliates in a given country, a quarter of them three affiliates, 10 per cent of them have four affiliates, so on and so forth. The fact that there are multiple affiliates per firm in a host country is a potential problem for inference. In Section 3, we showed how aggregation of affiliates may cause aggregation bias in the firm-level estimations if there is within-firm competition between affiliates.

Another level in the aggregation is from firm to country. Going back to Table 3, looking at the number of firms in each country in 1998, it is seen that about 90 per cent of the observations come from larger and more developed countries. The majority of observations will therefore be of market-seeking FDI type when we examine the spatial correlation at the affiliate or firm level. However, when we aggregate to the country level and are left with 45 observations per year, these large and developed countries will not constitute the majority of observations anymore. Smaller or less developed countries, where the motive for an investment may be driven more from vertical specialisation may suddenly become important in regressions as a larger share of the observations are now of this type. Therefore, it is one of the important tasks of this paper to sort out the biases that might arise as one incrementally aggregates the data into larger units and changes the composition of the sample.

6. RESULTS

In this section, we report our empirical findings. We find extensive evidence that host-country and third-country sales (sales abroad) are a substitute in space at the affiliate and firm level. This is broadly consistent with the export-platform theory. Exports back to Sweden are complements in space and provide evidence of vertical specialisation and agglomeration of this type of activity. Furthermore, aggregating data to country level greatly biases the estimates of the spatial lag coefficient. Discussion focuses on the Heckman specifications; since in most cases, the inverse Mills ratio is statistically significant.[15]

a. Affiliate-level Results

(i) Interpretation of Covariate Effects

Let us first interpret the estimated coefficients on non-spatial covariates shown in Table 4. Since our primary interest is the spatial lag coefficient, we will be brief in our discussion of covariates and only report results on the affiliate level. As discussed in Section 4*a*, a full

[15] As discussed by Dolton and Makepeace (1987), the coefficient on the inverse Mills ratio does not have a clear economic interpretation.

TABLE 4
Affiliate-level Heckman Regressions, 1965–98

Variables	*(1) Ln(Exports to Third)*	*(2) Ln(Local Sales)*	*(3) Ln(Exports to Sweden)*
Spatial Lag	−1.227***	−1.171***	0.879***
	(0.029)	(0.023)	(0.022)
Spatial Error	0.969***	0.966***	−1.284***
	(0.013)	(0.011)	(0.034)
Ln(Market Potential)	0.633	0.063	−0.164
	(0.670)	(0.423)	(0.445)
Sales Affiliate	−0.084	−0.030	−0.003
	(0.072)	(0.050)	(0.075)
Age	0.023***	0.012***	0.007***
	(0.003)	(0.001)	(0.003)
Experience	0.101	0.249**	0.049
	(0.157)	(0.097)	(0.251)
Ln(Firm Size)	0.265	−3.820	−0.039
	(3.563)	(2.625)	(0.057)
Ln(R&D)	1.265	−0.069	0.040
	(1.955)	(0.967)	(0.034)
Treaty	0.774**	0.056	−0.346
	(0.302)	(0.174)	(0.236)
Tax Rate	−0.005	−0.001	−0.001
	(0.005)	(0.004)	(0.004)
Ln(GDP)	−0.637	−0.958*	1.048
	(0.831)	(0.538)	(0.727)
Ln(GDP/Pop)	1.212	1.230**	−0.822
	(0.865)	(0.593)	(0.841)
Ln(Open)	0.587	0.161	−0.439
	(0.363)	(0.233)	(0.275)
EU	0.755***	0.130	0.244
	(0.216)	(0.147)	(0.156)
NAFTA	0.927***	0.178	0.128
	(0.257)	(0.169)	(0.124)
ASEAN	1.813***	−1.330***	1.265*
	(0.603)	(0.505)	(0.758)
Mills	3.563***	1.757***	0.134
	(0.652)	(0.591)	(0.401)
Constant	−20.168	28.323	−8.072
	(23.766)	(18.638)	(9.062)
Sigma	1.073***	0.876***	0.906***
	(0.017)	(0.012)	(0.017)
Observations	2,953	2,659	2,966
Log-likelihood	−3067.0313	−3337.5875	−1841.6033
Wald test χ^2 (H_0: OLS) (*p*-value)	6,952***	10^4***	2639.768***
	(0.000)	(0.000)	(0.000)
LR test χ^2 (H_0: OLS) (*p*-value)	811.86***	1143.573***	572.051***
	(0.000)	(0.000)	(0.000)

TABLE 4 *Continued*

Variables	*(1)* *Ln(Exports to Third)*	*(2)* *Ln(Local Sales)*	*(3)* *Ln(Exports to Sweden)*
LR test χ^2 (H_0: Sp. Error) (p-value)	811.785***	1141.151***	566.703***
	(0.000)	(0.000)	(0.000)
LR test χ^2 (H_0: Sp. Lag) (p-value)	811.777***	1142.403***	571.155***
	(0.000)	(0.000)	(0.000)

Notes:
(i) All equations include year-fixed effects.
(ii) Robust standard errors in parentheses.
(iii) ***p < 0.01, **p < 0.05, *p < 0.1.

evaluation of the impact of covariates includes a more elaborate analysis estimating $(\partial Y_j/\partial X_{ki})$, whereas we focus on an approximation for $(\partial Y_i/\partial X_{ki})$.

We provide regression results for three different dependent variables: exports to third countries, local sales and exports to Sweden. For each dependent variable, Table 4 provides the affiliate-level Heckman regressions.[16,17] With the presence of spatial spillovers, interpretation of regression coefficients may include both a direct and an indirect effect.[18] Direct effects capture the effect of a change in an affiliate's covariate directly on that affiliate's sales. Indirect effects capture the spatial spillovers of a change in a covariate of one affiliate on sales of other affiliates and then through the spatial lag back on the sales of the first affiliate.[19] Our definition and interpretation of these effects follows approach in Kim et al. (2003), Small and Steimetz (2012) and Woodard et al. (2012).

Focusing our discussion on exports to third countries, we interpret the statistically significant coefficients. The age of the affiliate increases exports to third countries. A standard deviation increase in age (16.39 years) has a direct effect on the affiliate's exports to third countries of 37.7 per cent. Total effect on the affiliate is reduced by the spatial multiplier $(1/1-\rho) = 1/[1-(-1.227)] = 0.449$ since the negative spatial lag implies reductions in other affiliate sales which in turn feed back to the affiliate. The total effect of increasing age by the standard deviation on the affiliate's exports to third countries then is $37.7 \times 0.449 = 16.9$ per cent. The indirect effects working through the negative spillovers are 16.9–37.7 = −20.8 per cent.

[16] The test statistics comparing the spatial mixed model with OLS, spatial lag or spatial error are reported at the bottom of Table 4. When data-generating process involves anomalies, such as heteroscedasticity with a spatial pattern, Mur and Angulo (2009) find that the specification tests are more robust when moving from a general model (spatial mixed) to a specific model (OLS) for model selection. Discussion focuses on the spatial mixed models as for all three dependent variables, and the null hypotheses of simpler models are rejected.
[17] Appendix A provides the affiliate-level first-stage probit equations for the Heckman selection correction used to obtain the inverse Mills ratio.
[18] See Small and Steimetz (2012) for a discussion on pecuniary and technological spillovers that affect the extent to which the indirect effects should be considered. In our interpretation, we consider the full extent of the indirect effects.
[19] Total effects are obtained using a result from Kim et al. (2003) that the spatial multiplier for row-standardized matrices can be approximated by $1/(1-\rho)$. Indirect effects then approximate to $[(\beta_k/1-\rho)-\beta_k]$.

TABLE 5
Summary of Results at the Affiliate, Firm and Country Level

	(1) Affiliate Heckman	*(2) Firm Heckman*	*(3) Country Level*
Firm FE	Yes	No	No
Country FE	Yes	Yes	Yes
Ln(Exports to Third)			
Spatial Lag	−1.227***	−0.264***	0.132*
	(0.029)	(0.062)	(0.074)
Spatial Error	0.969***	0.395***	−0.242*
	(0.013)	(0.053)	(0.126)
Ln(Market Potential)	0.633	2.345***	3.690***
	(0.670)	(0.864)	(1.322)
Observations	2,953	2,000	248
Ln(Local Sales)			
Spatial Lag	−1.171***	−0.160***	−0.137
	(0.023)	(0.049)	(0.096)
Spatial Error	0.966***	0.352***	0.193
	(0.011)	(0.044)	(0.127)
Ln(Market Potential)	0.063	0.375	2.417*
	(0.423)	(0.589)	(1.313)
Observations	2,659	1,933	245
Ln(Exports to Sweden)			
Spatial Lag	0.879***	−0.230***	0.329***
	(0.022)	(0.069)	(0.084)
Spatial Error	−1.284***	0.399***	−0.389***
	(0.034)	(0.056)	(0.136)
Ln(Market Potential)	−0.164	0.671	−1.852
	(0.445)	(0.864)	(1.130)
Observations	2,966	2,000	248

Notes:
(i) Robust standard errors in parentheses.
(ii) ***p < 0.01; *p < 0.1.

Signing a tax treaty with Sweden has an effect on affiliates' exports to third countries. The direct effects imply a 117 per cent increase in affiliate exports to third countries, but the negative indirect effect causes the total effect to be approximately 42 per cent.[20] That is again because the negative spillovers across affiliates are lowered and then these negative effects feedback. Joining one of the trade blocks during the sample period increased affiliate exports to third countries. While the coefficient estimates imply large direct effects (113 per cent for new EU members, 153 per cent for NAFTA and 513 per cent for ASEAN), these are mediated through the negative spatial spillovers and indirect effects. Then, the total effects of each of these trade blocks amount to 40 per cent for new EU members, 52 per cent for NAFTA and 126 per cent for ASEAN.

[20] For interpretation, coefficients on dummy variables are transformed by $100 \times [\exp(\beta_k) - 1]$ (Wooldridge, 2009).

(ii) Spatial Effects

Let us now turn to our main variables of interest. The *spatial lag* coefficient, *the spatial error* coefficient and *Market Potential* coefficient are summarised in Table 5. In column (1), we provide affiliate-level estimates employing the Heckman approach discussed above. In the affiliate-level regressions using the full sample, for the third-country and host-country sales the spatial lag coefficient implies that a 1 per cent increase in the spatially weighted average of other affiliates sales decreases the affiliate's own sales by about 1.2 per cent. In affiliate-level regression for exports back to Sweden, the spatial lag coefficient is positive and statistically significant. This positive spatial lag could be explained vertical specialisation in production networks across affiliates that export back to Sweden.

In the affiliate-level analysis including country and firm-fixed effects, we find no statistically significant market potential effects. Yet, when we exclude country-fixed effects, we find positive *Market Potential* coefficients.[21] This indicates that the negative spatial lags are consistent with the export-platform theory for exports to third countries and local sales but that there is insufficient time-series variation in *Market Potential* for its effect to be identified.

b. Firm-level Results

To determine the effect of data aggregation, we next aggregate the data to firm level within each country. We provide the coefficients of the spatial variables from these regressions in column (2) of Table 5. As estimated by the spatial lag, the substitution of sales abroad by a firm across country borders has a much smaller effect than when we also allow for substitution of FDI within a country using affiliate-level data. At the firm level, a 1 per cent increase in the distance-weighted average of the firm's activities in other countries decreases sales by merely 0.26 per cent for exports to third countries and 0.16 per cent for local sales. Our simple model in Section 3 suggests that competition between the affiliates of multiproduct multinational is a potential mechanism that might generate this bias.

Consistent with export-platform FDI, we now find a positive market potential coefficient for exports to third countries. Because affiliates in a country may be vertically integrated, aggregating to firm level seems to facilitate the identification of the market potential effect here.

Pure horizontal theory implies a zero spatial lag coefficient for local sales, yet we continue to find a negative spatial lag. For exports back to Sweden, there is a switch in sign from positive spatial lag coefficient at the affiliate level to negative spatial lag coefficient at the firm level. To reconcile these latter results, we would need a more elaborate model than the one used in Section 3.

c. Country-level Results

Much of existing empirical literature uses country-level analysis. Thus, we aggregate our data to country level and conduct the spatial econometric analysis at the country level. By presenting results at three different scales (affiliate, firm and country level), we find a severe scale problem. Comparing columns (1) through (3) in Table 5 provides evidence of large and significant aggregation bias for all three variables. This bias is so large that the spatial lag

[21] These regressions are available upon request.

coefficient flips from negative to significantly positive for third-country exports. To highlight the severity of the aggregation bias in our results, we present the estimated spatial lag coefficients for exports to third countries in Figure 2, for local sales in Figure 3 and for exports back to Sweden in Figure 4.

For third-country and host-country sales, the general pattern implies that the negative spatial lag coefficient in affiliate-level results becomes increasingly less negative as we aggregate to higher level.

For exports back to Sweden, there is a curious switch in signs of spatial lag coefficients from positive at affiliate level to negative at firm level and back to positive at the country level. As suggested above, vertical specialisation in production networks could explain the positive spatial lag across affiliates that export back to Sweden.

The estimates provided in columns (2) and (3) in Table 5 and illustrated in Figures 2–4 show that aggregating from the firm level to the country level also tends to give rise to an aggregation bias, since the estimates of the spatial correlation switches sign going from negative to positive. This might hint to a different mechanism present when going from firm level to country level than when going from affiliate to firm level.

In Section 5, we pointed out that when the analysis is conducted at the country level, observations from smaller and less developed countries will make up the largest share of observations, even though most Swedish affiliates are located in a smaller number of developed countries. If investments in the former group are driven more by vertical specialisation with agglomeration, then aggregate level regressions will tend to give this motivation a greater weight than do regressions at the affiliate or firm level (where investments in large developed countries dominate and where market seeking is the dominating motive). At the

FIGURE 2
Aggregation Bias in Exports to Third Countries' Heckman Spatial Lag Coefficient

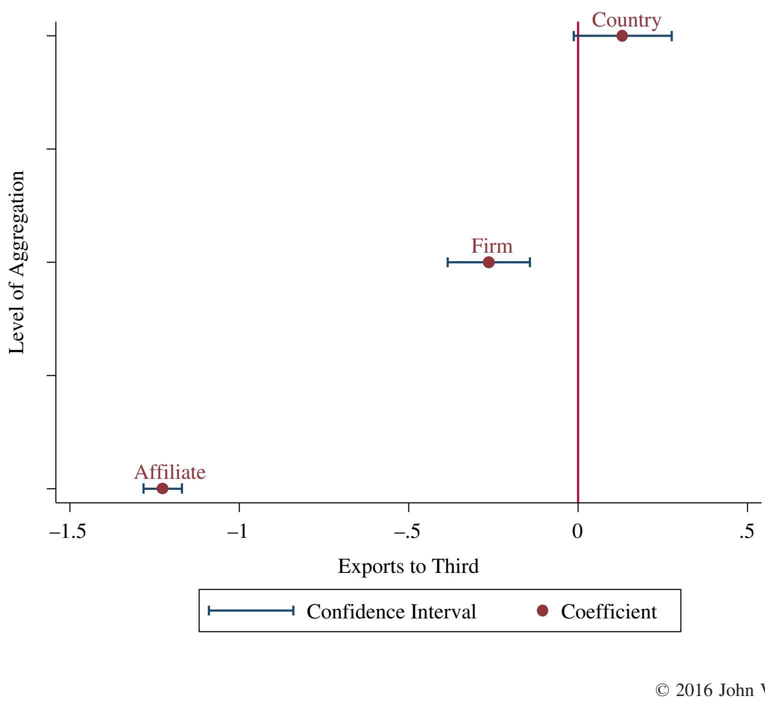


FIGURE 3
Aggregation Bias in Local Sales' Heckman Spatial Lag Coefficient

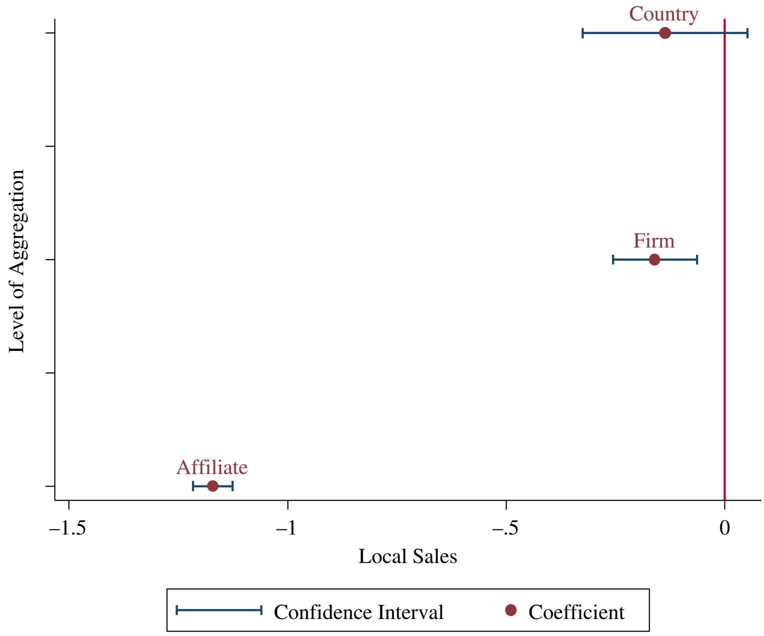
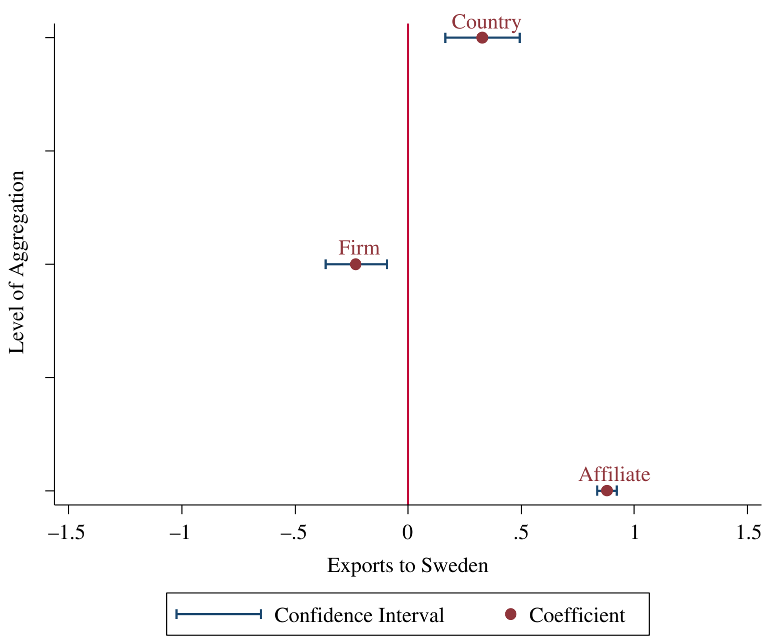


FIGURE 4
Aggregation Bias in Swedish Exports' Back to Sweden Heckman Spatial Lag Coefficient



host country level, where intrafirm competition cannot be observed and the influence of many firms is blurred, this might explain the positive spatial correlation we find in our country-level estimates.

Blonigen et al. (2007) also reported spatial interdependence that is scale sensitive when analysing US outbound FDI. In country-level analysis, they find positive statistically significant spatial lag coefficient for full, OECD and European samples, matching what we find for exports to third countries. Blonigen et al.'s disaggregated analysis estimates negative spatial lag coefficients for nine of the 11 industries evaluated (although only three of these spatial lags are statistically significant likely due to low degrees of freedom). Two industries with positive spatial lag coefficients in their analysis were 'petroleum' and 'chemical and allied products' industries (only 'petroleum' was statistically significant). That the latter two industries, so closely related to natural resources, show signs of agglomeration is no surprise. The general pattern of aggregation bias in their analysis matches what we present in this study for Swedish FDI – a negative spatial lag for disaggregate affiliate-level FDI and a positive spatial lag for aggregate country-level FDI. These findings point to the ecological fallacy in FDI estimations when aggregate data are used to test the firm-level FDI theories.

7. CONCLUSION

This paper endeavoured to understand FDI heterogeneity and offered new insights about aggregation issues in FDI estimations. Using spatial econometrics and data on Swedish MNCs' affiliate-level activity, evidence of different motivations for FDI was evaluated.

The results of our analysis show the importance of the multilayered nature of aggregation in FDI for empirical analysis. Like many other affiliates belonging to MNCs of other countries, Swedish affiliates are nested within a hierarchy (affiliate, firm, country). The characteristics of the affiliate, as well as the level of nesting, determine affiliate activity. Our results indicate that Swedish FDI is a substitute in space. This is consistent with export-platform FDI for exports to third countries and local sales activity and with vertical FDI for exports back to Sweden.

For third-country and host-country sales, we estimate negative statistically significant spatial spillovers at the affiliate level, these spatial spillovers decrease in magnitude when data are aggregated to the firm–country level and are even more biased by aggregation to country level. For third-country sales, aggregation to country level actually flips the spatial spillovers to positive and statistically significant. This aggregation bias stemming from the scaling problem in FDI estimations is likely present in many of the country-level analyses in previous literature. An important task for future research should then be to develop theory to better understand the mechanisms through which this aggregation bias emerges.

As we have shown, using multiproduct models of FDI seems to be a promising route to take. These models naturally contain competition between affiliates within the same firm (by cannibalisation of revenues as in Baldwin and Ottaviano, 2001; or through competition over scarce organisation capital as in Yeaple, 2013): if estimates reveal a less negative spatial correlation between firms' aggregated activities in different host countries than between individual affiliates activities, regardless of the host country, this can potentially be rationalised by the fact that aggregating affiliate activities over mother firms in a host country only takes into account competition across borders. Aggregation or scaling up the estimating units over firms or countries, discards the effect of competition between affiliates in the same host countries, which weakens the spatial autoregressive relationship (at least in market-seeking activities).

Aggregation over firms in the same country may exacerbate the bias. Market-seeking investments are the primary motive for Swedish outward FDI as most affiliates are located in richer and/or larger developed countries. At the host country level, however, there is a single observation per country per year – regardless of the number of affiliates present. In effect, locations in developing countries where vertical specialisation seems to be the primary motive will then take up a larger share of the sample, potentially producing a more positive spatial lag at the country level than at more disaggregated levels.

On a final note, we have confined our attention to how aggregation bias impacts the estimated spatial lag coefficient, capturing the strength of spatial spillovers in affiliate sales. With this focus, we spent less effort in explicitly estimating the individual spillover effects from one affiliate to another and how aggregation bias impacts these effects. It would certainly be interesting to explore this issue further, taking advantage of methods that explicitly estimate the across-observations effect of control variables as suggested by LeSage and Pace (2009, 2010). Extensions could include exploring the impact of host country institutions. This is, however, left for future research.

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APPENDIX

TABLE A1
Heckman 1st Stage Selection Probit Model

Variables	*(1)* *Ln(Exports to Third)*	*(2)* *Ln(Local Sales)*	*(3)* *Ln(Exports to Sweden)*
Ln(Distance$_{SWE}$)	−0.002	−0.223**	−0.493***
	(0.048)	(0.109)	(0.046)
Labour intensive	0.633***	0.735***	0.247***
	(0.095)	(0.232)	(0.093)
Scale intensive	0.443***	0.376**	0.175*
	(0.090)	(0.183)	(0.090)
Differentiated goods	0.896***	0.085	0.656***
	(0.093)	(0.183)	(0.091)
Science-based goods	0.505***	−0.196	0.607***
	(0.133)	(0.261)	(0.131)
Ln(Market Potential)	0.325***	−0.429**	0.130
	(0.092)	(0.208)	(0.090)
Sales Affiliate	−0.037	0.048	0.067
	(0.078)	(0.194)	(0.075)
Age	0.011***	0.022***	0.011***
	(0.002)	(0.007)	(0.002)
Experience	−0.054	−0.071	0.353**
	(0.130)	(0.232)	(0.138)
Ln(Firm Size)	0.114***	0.145***	0.035**
	(0.018)	(0.034)	(0.017)
Ln(R&D)	0.059**	−0.012	0.046**
	(0.024)	(0.047)	(0.023)
Treaty	0.239**	0.205	−0.307**
	(0.120)	(0.255)	(0.127)
Tax Rate	−0.004	−0.004	0.002
	(0.004)	(0.009)	(0.003)
Ln(GDP)	0.044	0.157*	0.000
	(0.039)	(0.089)	(0.040)
Ln(GDP/Pop)	0.357***	0.301**	0.351***
	(0.059)	(0.135)	(0.067)
Ln(Open)	0.081	−0.216	−0.162
	(0.095)	(0.203)	(0.102)
EU	0.214**	0.063	0.022
	(0.087)	(0.188)	(0.083)
NAFTA	0.281**	0.417	0.142
	(0.132)	(0.449)	(0.122)
ASEAN	0.074	−1.011**	0.705**
	(0.299)	(0.425)	(0.334)
Constant	−8.276***	1.264	−1.417
	(1.237)	(2.561)	(1.198)
Observations	2,953	2,659	2,966
Log-likelihood	−1483.1697	−249.12643	−1738.4515

Notes:
(i) All equations include year-fixed effects.
(ii) Robust standard errors in parentheses.
(iii) ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.