# Horizontal or Backward? FDI Spillovers, Input-Output Tables, and Industry Aggregation

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**Abstract**

This study explores the importance of the level of industry aggregation, in the analysis of FDI spillover effects. The horizontal-vertical classification in empirical work is typically determined by the level of industry aggregation found in input-output tables used for calculating vertical spillover variables. For a panel of Romanian firms we find that the use of aggregated input-output tables gives rise to an upward bias of the horizontal spillover coefficient and biases results against finding significant backward spillovers. Assuming that the true nature of the backward spillover is to be found in a supplier-customer relationship, we show that -for the detailed IO-tables- including within industry intermediate supply and use of goods results in a larger impact of the backward spillover on the level of $TFP$. For aggregated IO-tables including within industry intermediate supply and use of goods does not reduce the biases indicated above.

JEL Classification: F2
Keywords: input-output tables, foreign direct investment, spillovers

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# 1 Introduction

FDI spillovers can be broadly defined as the impact of foreign firms' presence on domestic firms' economic performance. The standard approach in the empirical literature is to analyze spillovers as additional inputs explaining total factor productivity (TFP) in a production function framework. In this literature, horizontal spillovers are distinguished from vertical effects. Horizontal spillovers occur between firms in similar stages of the production chain, while vertical spillovers occur between firms in customer-supplier relationships. Horizontal spillovers have received widespread attention at least since Caves (1974). The vertical spillover discussion launched by McAleese and McDonald (1978) and Lall (1980) languished for nearly two decades before theoretical work by Rodriguez-Clare (1996) and Markusen and Venables (1999) and empirical work by Javorcik (2004) revived the interest in vertical spillovers as a more likely channel for (positive) productivity spillovers. Since then, a considerable amount of empirical work has focused on vertical spillovers and has found that especially backward spillovers are more likely to generate a substantial positive impact on domestic firms' TFP, often outweighing horizontal spillovers, for which the empirical evidence is much more mixed (see Görg and Greenaway, 2004; Crespo and Fontoura, 2007; Meyer and Sinani, 2009). Based on a meta-analysis of 3626 estimates of backward spillovers (covering literature up to March 31 2010), Havranek and Irsova (2011) confirm that the average spillover to suppliers is economically significant.

In a recent contribution, Barrios et al. (2011) challenge some of the implicit assumptions underlying the measure for vertical spillovers proposed by Javorcik (2004). For a panel of Irish firms, they find that alternative measures yield different results. Although Barrios et al. (2011) deal with several important issues, including the use of input-output tables in constructing spillover variables, they do not consider the level of industry aggregation in these tables as potentially affecting spillover effects. However, given the way horizontal and vertical spillover variables are typically defined and constructed, the level of industry aggregation is crucial in discriminating between horizontal and vertical spillovers. Following Caves (1974), most empirical work defines the variable to capture the horizontal spillover potential as the share of industry output produced by foreign firms. Because firm-level data on linkages with foreign affiliates are usually unavailable, variables to capture vertical spillover potential are calculated -following Javorcik (2004)- as a weighted average of foreign presence (measured by the horizontal variable) in industries upstream and downstream of a domestic firm in a given industry. These weights are technical coefficients derived from input-output (IO) tables, conveying industry-level relationships with upstream and downstream industries. Therefore the input-output tables' level of industry aggregation generally determines the definition of horizontal and vertical spillovers. Clearly, the more aggregated the input-output tables used, the more likely that the horizontal spillover variable will also capture customer-supplier relationships. Recent work by Alfaro and Charlton (2009) makes a similar point in a closely related matter: the classification of multinational firms' investment as horizontal or vertical. They show for a large sample of multinational firms that due to a finer level of detail in industry classification a lot more multinational investment than previously thought should be classified as vertical rather than horizontal.

This paper analyzes the impact of the level of industry aggregation on both horizontal and vertical spillovers for a panel of Romanian firms. We analyze spillovers using both a time series of detailed input-output tables and a series of these tables collapsed to a higher level of industry aggregation. For a data set of Romanian manufacturing firms, we find that the use of an aggregated input-output table results in an upward bias of the horizontal spillover coefficient and biases results against finding significant backward spillovers. Consequently, input-output tables with a sufficiently detailed industry classification are required in the study of FDI spillover effects. The implications of this finding can be relevant in other fields in which input-output tables are used as well, for instance in the field of industrial organization and in the analysis of (greenhouse gas) emissions and energy uses (e.g. see Chen and Chen, 2011). Furthermore, assuming that the true nature of the backward spillover is to be found in a supplier-customer relationship, we show that -for the detailed IO-tables- including within industry intermediate supply and use of goods results in a larger impact of the backward spillover on the level of $TFP$. For aggregated IO-tables including within industry intermediate supply and use of goods does not reduce the biases found earlier.

The structure of the paper is as follows. Section 2 provides a discussion of spillover measurement and the role of industry classification and input-output tables. In section 3, the empirical approach and the data are described. Section 4 presents estimation results and section 5 concludes by summarizing the key findings of our analysis.

# 2 Spillover measurement

Figure 1 illustrates the role of horizontal and vertical spillover effects in the supply chain. Horizontal or intra-industry spillovers run from multinational firms to their domestic counterparts. Vertical or inter-industry spillovers, on the other hand, run from MNEs to domestic firms that are upstream or downstream of the multinational firm in the supply chain. With respect to the latter, the literature distinguishes vertical spillovers that occur through contacts between foreign firms and their upstream local suppliers (backward spillovers) from

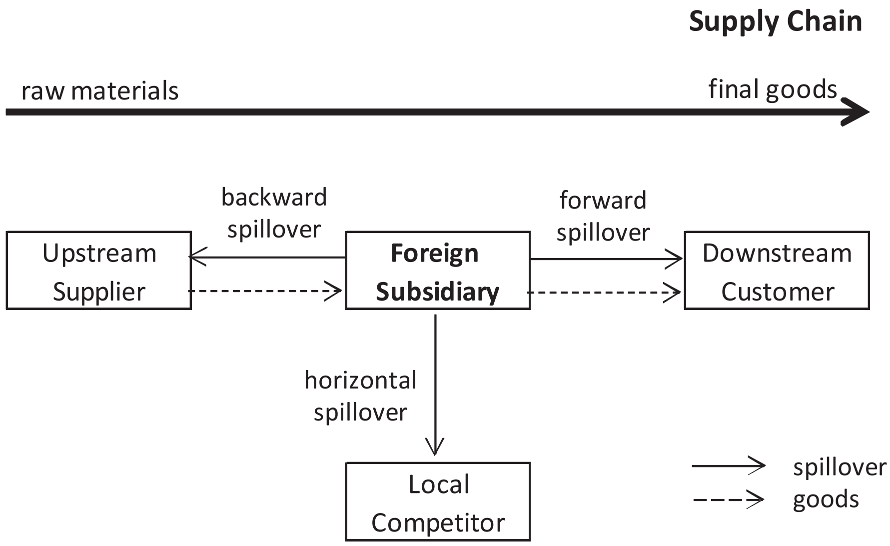


Figure 1: Horizontal, backward and forward spillovers in the supply chain.

those that occur through contacts between foreign firms and their downstream customers (forward spillovers).

The methodology to calculate variables that capture FDI spillover potential draws on work by Caves (1974) and Javorcik (2004). Horizontal or intra-industry spillover variables are calculated as follows:

$$Horizontal_{jt} = \frac{\sum_{i \in j} ForeignShare_{it} * Y_{it}}{\sum_{i \in j} Y_{it}} \tag{1}$$

where $Y_{it}$ is output produced by firm $i$ in industry $j$ in year $t$ and $ForeignShare_{it}$ is the share of foreign participation in firm $i$ in year $t$. For a firm to be classified as foreign at least a single foreign investor with at least 10% of shares is required. $Horizontal_{jt}$ then captures the degree of foreign presence in industry $j$ at time $t$ by the share of industry $j$'s output produced by foreign firms.

The backward spillover variable for industry $j$ measures foreign presence in industries $c$ supplied by industry $j$ at time $t$ and is typically calculated as follows:

$$Backward_{jt} = \sum_{c \, if \, c \neq j} \gamma_{jct} * Horizontal_{ct} \tag{2}$$

$Backward_{jt}$ is a weighted average of $Horizontal$ in the sourcing industries $c$, where the weights are the technical coefficients $\gamma_{jct}$, i.e. the share of industry $j$'s total intermediate supply that is supplied to each industry $c$. These technical coefficients are derived from input-output tables for intermediate consumption (typically final uses are not taken into account, *cf. infra*). Following Javorcik (2004), inputs supplied within the same industry are commonly excluded as these are already part of the horizontal spillover (hence $c \neq j$). $Backward$ serves as a proxy for the potential linkages between MNEs and their local suppliers.

The forward spillover variable for industry $j$ is constructed in a similar way:

$$Forward_{jt} = \sum_{r\, if\, r \neq j} \delta_{jrt} * Horizontal_{rt} \quad (3)$$

In this case the technical coefficients $\delta_{jrt}$ correspond to the share of industry $j$'s inputs purchased from industries $r$ at time $t$. Inputs sourced within the same industry are excluded ($r \neq j$). The forward spillover is a proxy for the potential linkages between multinational firms and local clients.

The above mentioned definitions for empirical use thus put an explicit industry structure on the spillovers defined in Figure 1. Because these definitions rely on information from input-output tables (the $\gamma$s and $\delta$s), the level of industry aggregation in the IO-tables will generally determine the distinction between horizontal and vertical spillovers. Figure 2 illustrates how the level of industry aggregation affects the classification of spillover effects in horizontal and vertical effects. The upper panel of Figure 2 represents a stylized IO-table at an aggregated level, while the lower panel represents an IO-table at a more disaggregated level. In the aggregated table only three different industries can be distinguished: industries 1, 2 and 3. If FDI spillovers are calculated with this IO-table at hand, the grey-shaded areas (the diagonal) will refer to the horizontal spillover variable in equation (1) and following equations (2) and (3) they will be excluded from the vertical spillovers. If we move to the detailed IO-table in the bottom panel, there are now six different industries: $1a$, $1b$, $2a$, $2b$, $3a$ and $3b$. If FDI spillovers are analyzed using this detailed IO-table, one immediately sees that the grey-shaded horizontal spillover area becomes slimmer and that the relationship between for example industries $1a$ and $1b$ is now of vertical nature. Thus, several firms that were previously part of a single industry are now classified into different industries in a client-supplier relationship. The implications are obvious. Because the more detailed IO-table does allow for finer sourcing and supplying patterns, much more relationships will be counted as vertical than on the basis of the aggregated table. Additionally, the more detailed IO-table also allows for a more accurate detection of sourcing from, and foreign presence in industries that are also vertically linked in the aggregated IO-table. Since industry $1a$ cannot be distinguished from $1b$ when calculating backward spillovers for industry 2 or 3 in the upper table, there will be an aggregated backward spillover from industry 1 that masks potential

**Input-output table at aggregated industry level**

| Industry | | Intermediate consumption | | | | | | Final uses | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | | 2 | | 3 | | | |
| | | a | b | a | b | a | b | | |
| 1 | a<br>b | | | | | | | | |
| 2 | a<br>b | | | | | | | | |
| 3 | a<br>b | | | | | | | | |

**Input-output table at detailed industry level**

| Industry | | Intermediate consumption | | | | | | Final uses | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | | 2 | | 3 | | | |
| | | a | b | a | b | a | b | | |
| 1 | a | | | | | | | | |
| | b | | | | | | | | |
| 2 | a | | | | | | | | |
| | b | | | | | | | | |
| 3 | a | | | | | | | | |
| | b | | | | | | | | |

Figure 2: Stylized input-output tables at varying levels of industry aggregation.

differences between industries 1$a$ and 1$b$.[1] If there is a substantial variation in technical coefficients and foreign presence between the $a$ and $b$-parts of industries, the availability of a more detailed input-output table is likely to affect backward and forward spillover variables as well.

Thus, to disentangle horizontal from vertical spillovers, the level of industry aggregation is essential. In addition to national data sources, both the OECD and Eurostat provide harmonized input-output tables. These tables are fairly aggregated, however. The dimension of the OECD tables is 48x48 industries. Out of these 48 industries, 22 are manufacturing indus-

[1]Suppose industry 2($a/b$) is a big supplier of industry 1$b$ but not of 1$a$, and that there is a large foreign presence in 1$b$ but not in 1$a$. This type of information is likely to be largely lost in the aggregated IO-table because both the technical coefficient and the $Horizontal$-variable will refer to the entire industry 1.

tries. Eurostat tables typically have a 59x59 dimension (i.e. NACE 2-digit classification[2]). 23 out of the 59 industries are manufacturing industries. In this paper, we use an IO-table for the Romanian economy that consists of 105 industries (detailed IO-table henceforth) which roughly correspond to NACE 3-digit industries. Out of these, 61 are manufacturing industries.[3] The IO-tables and the industry code conversion to the NACE classification were obtained from the Romanian Statistical Institute (RNSO). In order to analyze the impact of the level of industry aggregation on horizontal and vertical spillover effects, we collapse the detailed table to NACE 2-digit level (aggregated IO-table henceforth) and calculate horizontal and vertical spillover variables on the basis of both the aggregated and detailed IO-tables. Table A.1 in Appendix lists the mapping of the Romanian classification into the NACE 2-digit and 3-digit classification schemes. In terms of Figure 2, the detailed table for e.g. the year 2005 reveals for 2-digit industries 15 (food), 24 (chemicals), and 26 (non-metallic mineral products) -which have 9, 7, and 8 3-digit sub-industries respectively- that the off-diagonal elements within the same 2-digit industry account for 26, 47, and 37 percent of the *within NACE 2-digit* intermediate supply. As a share of *total* intermediate supply, the numbers are 12.1, 6.5, and 4.3 percent. For sub-industries, on average about 87% of firms in the same NACE 2-digit industry belongs to a different detailed sub-industry.

Backward spillovers have received such widespread attention because of the expectation that customer-supplier relationships are more inclined to result in positive spillover effects than competitive relationships (horizontal spillovers). If one defines backward spillovers as effects that originate from customer-supplier relationships, it is sensible not to exclude the diagonal elements from the backward calculation because these numbers do refer to intermediate use and supply of goods.[4] This may have important implications as even in our detailed IO-tables diagonal elements are non-negligible (in 2005, on average about 15% of intermediate supply by manufacturing industries is within the same 3-digit industry). We therefore investigate the impact of including the share of intermediates supplied or bought within the industry in the vertical measures. We do this for both the aggregated and detailed input-output tables.

Figure 3 gives an idea of the distribution and values of the backward spillover variable in the time dimension across the different definitions mentioned above. The figure shows backward variables according to the zero-diagonal definition (equation 2) for both the aggregated and detailed IO-tables, and using the non-zero-diagonal definition for the detailed IO-tables.

[2] Nomenclature des Activités économiques dans la Communauté Européenne.

[3] For the industries "Processing of nuclear combustibles" and "Armament and ammunition" there is no data available reducing the number of manufacturing industries to 59.

[4] Javorcik (2004) finds no difference when adding diagonal elements (see her footnote 18).

The boxplots are based on an industry-level data derived from our firm-level sample discussed below (i.e. 23 manufacturing industries for the aggregated IO-tables, 59 for the detailed IO-tables; period 1996-2005). The figure illustrates that the value of the spillover variable tends to increase with the different definitions. Going from the zero-diagonal aggregated IO-variable to the zero-diagonal detailed IO-variable implies an increase, because the pool of non-diagonal elements rises. Going to the non-zero-diagonal detailed IO-variable implies a further increase, because the non-zero-diagonal elements are accounted for now. Going from aggregated to detailed IO-variables also implies an increase in dispersion of the backward variable. The underlying horizontal spillover variables calculated as in equation (1) are shown in Figure 4, again for the aggregated and detailed IO-tables. As expected, going from aggregated to detailed IO-tables is associated with a growing dispersion for the horizontal spillover variable, but not in terms of values. Both Figures 3 and 4 illustrate the rising importance of foreign firms in the Romanian economy over the sample period.

< insert Figure 3 >
< insert Figure 4 >

The technical coefficients in equations (2) and (3) are traditionally only derived from the intermediate supply and use part of the input-output table. However, from Figure 2 one can infer that a given industry not only supplies intermediate goods, but also produces goods for final uses. Clearly, the extent to which an individual industry is involved in producing other industries' intermediate supply relative to production for final uses is a potential modifier of backward spillover effects. We can take this aspect into account by recalculating the backward spillover variable using a different set of technical coefficients. Generally, 'backward' technical coefficients for industry $j$ (the $\gamma$s in equation (2)) will be calculated according to equation (4), i.e. by dividing each cell of the intermediate consumption part of the IO-table in row $j$ by the row total, the total intermediate supply by industry $j$. The alternative that takes final uses into account is given by equation (5).

$$\gamma_{jc} = \frac{intermed_{jc}}{\sum_c intermed_{jc}} \tag{4}$$

$$\gamma'_{jc} = \frac{intermed_{jc}}{final_j + \sum_c intermed_{jc}} \tag{5}$$

The value of the backward spillover variable based on the $\gamma'$s in equation (5), $Backward^{final}$, will be smaller for industries that are relatively more directed towards production for final uses. The new variable can be obtained by replacing the $\gamma$s in equation (2) with $\gamma'$s.

It is straightforward to show that this is similar to premultiplying the backward spillover variable defined in equation (2) with $\sum_c intermed_{jc}/\left(final_j + \sum_c intermed_{jc}\right)$. Therefore $Backward^{final}$ can be seen as an interaction between $Backward$ and the share of intermediates in total industry ouput. Given this interpretation, we will include both variables simultaneously in a single regression.

# 3 Empirical Approach and Data

## 3.1 Empirical Approach

Following Javorcik (2004), FDI spillovers are analyzed in a production function framework where they are considered as additional 'inputs' explaining total factor productivity. Best practice is defined by Havranek and Irsova (2011) as a study that uses firm-level data, computes $TFP$ by a method that accounts for the endogeneity of input demand, estimates the regression in differences, and controls for sector fixed effects, sector competition, and demand in downstream sectors[5]. Following these guidelines, we specify equation (6) as our basic-level model where firm-level $TFP$ of firm $i$ in industry $j$ at time $t$ is related to FDI spillover variables, $FDI_j$, and a set of industry controls, $Z_j$. As in Javorcik (2004), the set of control variables $Z_j$ consists of a Herfindahl index of industry concentration and a demand index.

$$TFP_{ijt} = \alpha_i + \psi_1 f\left(FDI_{jt-1}\right) + \psi_2 Z_{jt-1} + \xi_{ijt} \tag{6}$$

Equation (6) is first-differenced and region ($\alpha_r$), industry ($\alpha_j$), and time ($\alpha_t$) dummies are added. We further include firm age and the lagged level of firm size (measured by real output) as determinants of $TFP$ growth. Equation (7) is estimated by OLS. Standard errors are clustered at the industry-year level because some of the variables are at the industry-level while estimation is at the firm-level (see Moulton, 1990).

[5]Downstream foreign entry could increase demand for intermediate products which might result in scale economies. To separate this effect, the regression includes demand for intermediates following Javorcik (2004) calculated as:

$$demand_{jt} = \sum_k a_{jk} * Y_{kt}$$

where $a_{jk}$ is the IO matrix coefficient indicating that in order to produce one unit of good $k$, $a_{jk}$ units of good $j$ are needed. $Y_{kt}$ stands for industry $k$ output deflated by an industry-specific deflator.

$$\Delta TFP_{ijrt} = \psi_1' \Delta f\left(FDI_{jt-1}\right) + \psi_2' \Delta Z_{jt-1} + \delta_1 age_{it} + \delta_2 size_{it-1} + \alpha_t + \alpha_j + \alpha_r + \varepsilon_{ijrt} \quad (7)$$

The estimation of $TFP$ is complicated by the endogeneity of inputs since the input choice of a firm is likely to be based on its productivity (see Griliches and Mairesse, 1995). A number of authors have proposed alternative estimation methods to obtain an unbiased estimate of TFP. The dynamic panel data setup of Blundell and Bond (1998) (DPD) and the semi-parametric approaches of Olley and Pakes (1996) (OP) and Levinsohn and Petrin (2003) (LP) are commonly used. In the semi-parametric approaches, a proxy is introduced to handle the endogeneity bias. OP use investment as a proxy[6], while LP opt for material inputs, arguing that investment is not a good proxy because it is lumpy and does not respond smoothly to the productivity shock (see also Petrin, Poi and Levinsohn, 2004). More recently, Ackerberg, Caves and Frazer (2008) (ACF) proposed an alternative semi-parametric procedure to deal with potential collinearity issues in OP and LP. As the discussion is still ongoing[7], we check robustness with respect to a number of alternative estimators. Finally, we also check robustness with respect to functional form and replaced the Cobb-Douglas specification with a translog specification (TL) that is estimated by OLS. Note that while $TFP$ estimates are obtained from production functions estimated by NACE 2-digit manufacturing industry, equation (7) pools domestic firms from all manufacturing industries.

## 3.2 Data

We use a Romanian firm-level panel data set to analyze FDI spillover effects from firms in manufacturing and services industries on Romanian manufacturing firms. The data span the period 1996-2005 and are limited to firms with at least five employees on average. The data set was further trimmed for outliers by removing the top and bottom percentiles of the annual growth rates of real operating revenues, real capital, labour, and real material inputs.[8] The firm-level data are drawn from the Amadeus database by Bureau Van Dijk Electronic Publishing. The Amadeus database holds financial and ownership information on public and private companies across Europe (Bureau Van Dijk, 2011). In order to get a full overview of

[6] We apply the procedure from Amiti and Konings (2007) to calculate investment from our data.

[7] Other recent efforts include $TFP$ estimation based on firm-level quantity data ($TFPQ$) rather than deflated revenue data ($TFPR$). Unfortunately, we have no data on quantities. Results should therefore be interpreted with this caveat in mind.

[8] If the ''outlier' is the first or last observation for a specific firm and other data points are normal, the other firm-year data are kept. If not all observations for this firm are dropped from the data set.

financials and ownership through time, multiple DVDs published by Bureau Van Dijk were used to construct the database.[9] Nominal data were deflated with industry price-level data at NACE 2-digit level. Price-level data was extracted from the Statistical Yearbook of the Romanian Statistical Institute (RNSO) and the Industrial Database for Eastern Europe from the Vienna Institute for International Economic Studies (WIIW). To construct real output ($Y$), operating revenues are deflated with producer price indices. Labour ($L$) equals the number of employees. Real capital ($K$) is tangible fixed assets deflated by the average of the following industry deflators: machinery and equipment (NACE 2-digit 29), office machinery and computing (30), electrical machinery and apparatus (31), motor vehicles, trailers and semi-trailers (34) and other transport equipment (35). Real material inputs (M) are obtained by deflating material inputs with a weighted intermediate input deflator, where weights are based on the IO-tables. IO-tables in a Romanian industry code classification (approximately NACE 3-digit) were obtained from the RNSO. Since we have a time-series of input-output tables, the obtained technical coefficients are time-varying.

The subset of Romanian firms in the Amadeus database is known for its excellent coverage (see a.o. Altomonte and Colantone, 2008). Although Romania had several features that make it an attractive country to invest in (e.g. its labour pool, resources and geographic location), it started to attract foreign investors' attention only in the late 1990s. FDI started entering after several privatization and market access reforms had been conducted (UNCTAD, 2003). Macroeconomic stabilization, an improved business environment, and EU candidacy, resulted in a sharp increases in FDI inflows after 2004, turning Romania into one of the main recipients of foreign investment in South-East Europe (OECD, 2005; UNCTAD, 2005). FDI in Romania is concentrated in the manufacturing industries and the main investors are European countries (80% of the total FDI stock (Pauwels and Ionita, 2008)).

Some summary statistics are provided in Tables 1 and 2. Table 1 lists the annual number of firms and the entry and exit rate of all firms and of the subsample of foreign firms. The percentage of foreign-owned firms operating on the Romanian market in our sample increased from 16% in 1996 to 22% in 2005. The 2003 exit rate is high, but this pattern is confirmed by the pattern in the Romanian Trade Register (Trade Register data also include agriculture and services though). Table 2 lists summary statistics both for domestic and foreign firms. The stylized facts commonly found in the literature are confirmed in our data set. Foreign firms are larger in terms of employment and capital, produce more output and are more productive. The latter holds across different estimation techniques.

[9] A single issue of the database is a snapshot in terms of the ownership information and firms that exit are dropped from the next issue of the database.

< insert Table 1 >

< insert Table 2 >

# 4 Results

This section presents results of different sets of estimations of specification (7). Tables 3, 4, and 5 all consist of an upper and a lower part. In each case, the upper part presents results based on the aggregated IO-table, the lower part results based on the detailed IO-table. For the sake of clarity and in order to keep the tables manageable, we do not report control variables. Regressions always include time, industry, and region dummies. Further control variables are firm age, firm size, downstream demand, and industry competition. We consider horizontal, backward and forward spillovers. The different columns in tables 3, 4, and 5 present results for alternative $TFP$ estimation methodologies and alternative functional forms of the production function. We show results for $TFP$ measures based on Cobb Douglas specifications applying the OP, ACF, LP, DPD and fixed effects (FE) estimators in columns 1-5. In column 6, our TFP measure is obtained from a translog specification estimated by OLS. The ACF and LP estimations are value-added based, the others are output based.

< insert Table 3 >

We go along with what Havranek and Irsova (2011) label the "ideal study design" and estimate (7) by OLS. We start by applying the standard definitions (1), (2), and (3) of the spillover variables and calculate spillovers for both the aggregated and detailed IO-tables. Table 3 shows the results. The upper part of the table presents results for spillovers (and industry-level controls) at the aggregated industry-level, while the lower part of the table presents results for spillovers at the detailed industry-level. At the aggregated level, we observe significant and important positive horizontal spillovers, significantly negative forward spillovers, and some limited evidence of significant positive backward spillovers.

The lower part of the table, however, reveals important implications of switching to a more detailed IO-table. Forward spillovers are still negative, but become insignificant. Point estimates for backward spillover effects decrease a little, but the effects are now highly significant and positive. Horizontal spillovers remain significant and positive, but point estimates decrease by about 40%. These findings suggest that the use of an aggregated IO-table results in an upward bias of the horizontal spillover coefficient and biases results against finding significant backward spillovers. Clearly, this might be driven by the use of an aggregated IO-table that results in classifying a considerable amount of vertical relationships as horizontal.

< insert Table 4 >

Is it possible to reduce these biases in the absence of a detailed IO-table? Since customer-supplier relationships are expected to be more inclined to result in positive spillover effects than competitive relationships, the inclusion of within industry supply and use in the vertical spillover variables could be a potential solution. Such an approach might reconcile differences between results on the basis of the aggregated and detailed IO-tables, because within industry supply and use that refers to customer-supplier relationships is always included in the vertical spillovers, regardless the level of aggregation in the input-output tables. Table 4 presents results for vertical spillover variables that do include *within* industry supply and use. The upper part of Table 4 reveals a fairly limited impact for results based on the aggregated IO-tables when compared to Table 3. The tendency of the effect even runs counter to expectations. The horizontal coefficient increases marginally and remains significant at conventional levels, although the level of significance drops a little. The point estimate for the backward spillover coefficient, however, decreases and loses significance. For the forward spillover we obtain a similar conclusion: the point estimate decreases both in absolute value and in terms of the significance level. Taking within industry supply and use into account therefore does not seem to offer a solution for the upward bias in the horizontal spillover coefficient and the lack of a significant backward spillover using the aggregated IO-tables. The lower part of Table 4, on the other hand, does reveal important implications of including within industry supply and use in spillover variables calculated using the detailed IO-tables. The horizontal effect now disappears. It is insignificant, not only as opposed to the results using the aggregated IO-table, but also as opposed to the 'zero-diagonal' results in the lower part of in Table 3. The point estimate is also much smaller and decreases by about 70% compared to the upper part of the table. The forward spillover disappears as well. The backward effect again becomes statistically significant when the detailed industry classification is used rather than the aggregated classification.

< insert Table 5 >

In Table 5 we add the interaction between the backward spillover variable and the share of intermediate supply in total industry output to the specification from Table 4. Doing so, we test whether industries' relative involvement in intermediate supply affects backward spillovers. The interaction effect turns out to be insignificant. Results on the other variables confirm our findings from 4. Backward spillovers at the detailed industry classification see their significance levels drop, but this is likely to be due to the fairly high correlation with the interaction variable. Clearly, data on output for intermediate supply at the firm-level might bring more insight, but as in most firm-level data sets information this detailed is not available.

< insert Figures 5 and 6 >

In addition to the size and statistical significance of the coefficients, Figures 5 and 6 show the contribution to firm-level ACF $TFP$ of the 1996-2005 mean horizontal and backward spillover variables for NACE 2-digit industries 15 and 24 (bars on the left hand side of each figure) and their 3-digit sub-industries (right hand side). In the spirit of equation (6), the numbers in the Figures are obtained as the coefficients from the upper part of Table 3 - the standard benchmark in most of the literature- multiplied by the average of the level of the respective spillover variables over the sample period in the respective industries for the aggregated results (NACE 2-digit, left bar). For the detailed results (NACE 3-digit, bars on the right), the coefficients from the ACF specification in Table 4 are multiplied by the average values of the respective spillover variables. Both figures clearly show that the use of the aggregated IO-tables implies a horizontal spillover that is considerably larger than the horizontal spillover found for any of the sub-industries using the detailed table. With respect to the backward spillover we have the opposite result, and find that the contribution to firm level ACF $TFP$ is larger when using the detailed IO-tables for 15 out of the 16 sub-industries than when using the aggregated tables. As the share of the diagonal elements in total intermediate supply is much larger for industry 15 than 24, the difference in the size of backward spillover effects between aggregated and detailed IO-tables is much larger for industry 15.

# 5 Conclusions

This paper studies the relation between the level of industry aggregation in input-output tables and the classification of FDI spillovers into horizontal and vertical effects and its impact on empirical results. To this end, we employ a data set of Romanian manufacturing firms and a time-series of detailed input-output tables. We then collapse the input-output tables to a higher level of industry aggregation to infer differences in spillover effects found using input-output tables at different levels of industry aggregation. We find that the use of an aggregated input-output table results in an upward bias of the horizontal spillover coefficient and biases results against finding significant backward spillovers. If one believes that the true nature of the backward spillover is to be found in a customer-supplier relationship, within industry intermediate supply and use of goods should not be excluded from the definition of backward (and forward) spillovers. Including within industry intermediate supply and use in the definition of vertical spillovers does not reduce the biases found for the aggregated IO-tables. For the detailed IO-tables, we do find a larger impact on the level of $TFP$ of the backward spillover when within industry intermediate supply and use are accounted for.

The results in this paper naturally imply the question whether links between (foreign and domestic) firms should not be identified at an even more detailed level. At the limit, one would be interested in information of links at the firm-level. Information this detailed is unfortunately rarely available (especially in a comparable way for a large number of firms). Moreover this type of data would be suspect to considerable endogeneity issues if foreign firms select the best local firms as their partners. In search for appropriate instruments, linkages derived from input-ouput tables would be a natural candidate since it is more difficult for foreign firms to switch industries when choosing their suppliers. Our results suggest to use input-output tables with a sufficiently detailed industry classification.

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Table 1: Overview of the number of firms, entry, exit and the penetration of foreign firms in the sample by year.

| | All firms | | | Of which foreign firms | | | |
|---|---|---|---|---|---|---|---|
| | # firms | entry | exit | # firms | entry | exit | penetration |
| 1996 | 14390 | | | 2240 | | | 0.16 |
| 1997 | 15610 | 1054 | 91 | 2608 | 312 | 32 | 0.17 |
| 1998 | 16759 | 995 | 190 | 2997 | 327 | 59 | 0.18 |
| 1999 | 18040 | 1197 | 761 | 3451 | 370 | 169 | 0.19 |
| 2000 | 19464 | 1845 | 301 | 3926 | 472 | 72 | 0.20 |
| 2001 | 20891 | 1374 | 506 | 4443 | 445 | 118 | 0.21 |
| 2002 | 21896 | 1224 | 988 | 4778 | 332 | 305 | 0.22 |
| 2003 | 22561 | 1335 | 2444 | 4881 | 297 | 490 | 0.21 |
| 2004 | 21508 | 1065 | 562 | 4817 | 313 | 168 | 0.22 |
| 2005 | 20946 | | | 4651 | | | 0.22 |

Table 2: Summary statistics of firm-level variables for the period 1996-2005 (all variables in logs).

| | All firms | | Domestic firms | | Foreign firms | |
|---|---|---|---|---|---|---|
| | mean | sd | mean | sd | mean | sd |
| real output | 13.63 | 2.08 | 13.46 | 2.02 | 14.32 | 2.15 |
| employment | 2.93 | 1.48 | 2.80 | 1.42 | 3.46 | 1.61 |
| real capital | 12.06 | 2.42 | 11.83 | 2.37 | 12.98 | 2.40 |
| real materials | 12.91 | 2.34 | 12.80 | 2.27 | 13.33 | 2.57 |
| tfp OP | 1.97 | 0.94 | 1.94 | 0.92 | 2.09 | 1.02 |
| tfp ACF | 5.74 | 1.52 | 5.69 | 1.52 | 5.95 | 1.47 |
| tfp LP | 7.00 | 1.85 | 6.94 | 1.87 | 7.22 | 1.75 |
| tfp DPD | 2.13 | 1.38 | 2.09 | 1.37 | 2.28 | 1.41 |
| tfp FE | 1.90 | 0.99 | 1.85 | 0.94 | 2.10 | 1.16 |
| tfp TL | 6.12 | 2.26 | 6.08 | 2.25 | 6.30 | 2.11 |

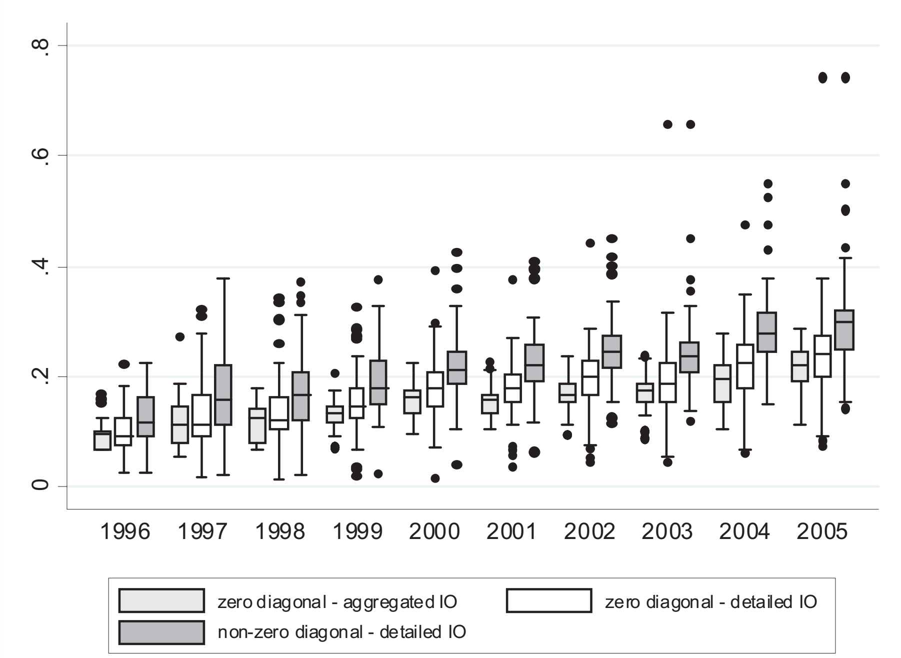


Figure 3: Boxplot of backward spillover variables calculated using aggregated and detailed IO-tables, and zero and non-zero-diagonal elements for the period 1996-2005.

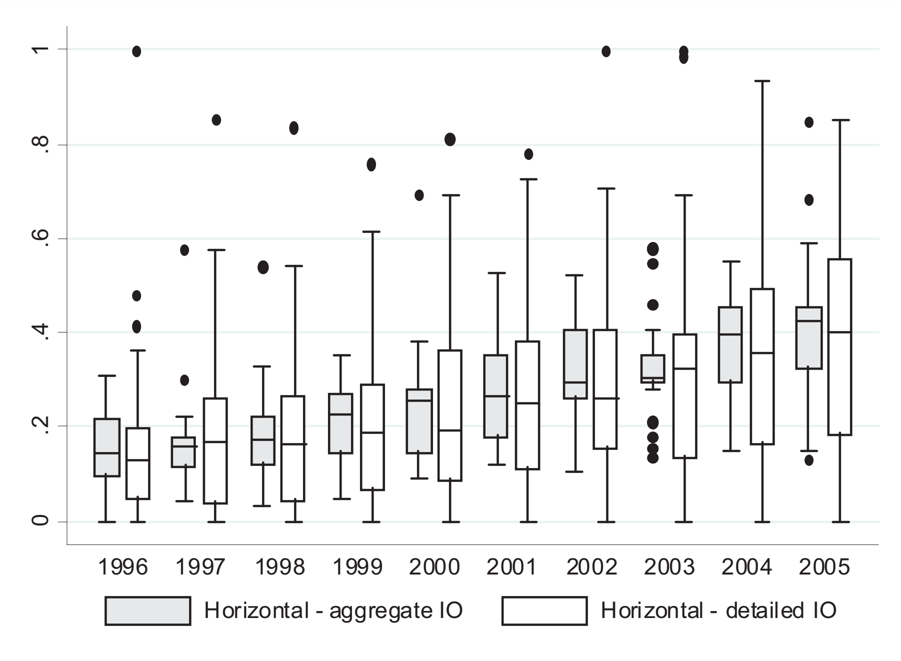


Figure 4: Boxplot of horizontal spillover variables according to the industry classifications found in the aggregated and detailed IO-tables for the period 1996-2005.

Table 3: FDI spillovers from all firms on Romanian manufacturing firms with at least five employees for the years 1996-2005 - vertical spillovers calculated using the zero-diagonal definition

| | (1) ACFva | (2) LPva | (3) OP | (4) DPD | (5) FE | (6) TL |
|---|---|---|---|---|---|---|
| | **aggregated - NACE 2-digit** | | | | | |
| *horizontal* | 1.908** | 1.894** | 0.578** | 0.543** | 0.553** | 0.579** |
| | [0.734] | [0.737] | [0.240] | [0.239] | [0.238] | [0.242] |
| *backward* | 2.553 | 2.440 | 1.426* | 1.367* | 1.412* | 1.287* |
| | [1.746] | [1.757] | [0.752] | [0.731] | [0.749] | [0.745] |
| *forward* | -3.999* | -4.025* | -1.728** | -1.667** | -1.720** | -1.651** |
| | [2.104] | [2.104] | [0.789] | [0.781] | [0.784] | [0.787] |
| $n$ | 73,255 | 78,710 | 96,681 | 96,728 | 96,728 | 96,728 |
| $R^2$ | 0.079 | 0.078 | 0.063 | 0.059 | 0.059 | 0.068 |
| | **detailed - Romanian NACE 3-digit equivalent** | | | | | |
| *horizontal* | 1.205*** | 1.192** | 0.344* | 0.327* | 0.328* | 0.346** |
| | [0.463] | [0.467] | [0.175] | [0.177] | [0.176] | [0.176] |
| *backward* | 2.146** | 2.141** | 1.059*** | 1.071*** | 1.055*** | 1.027*** |
| | [0.958] | [0.972] | [0.330] | [0.325] | [0.327] | [0.328] |
| *forward* | -1.748 | -1.781 | -0.894 | -0.865 | -0.904 | -0.868 |
| | [1.494] | [1.502] | [0.565] | [0.564] | [0.564] | [0.563] |
| $n$ | 73,255 | 78,710 | 96,681 | 96,728 | 96,728 | 96,728 |
| $R^2$ | 0.074 | 0.074 | 0.062 | 0.059 | 0.058 | 0.067 |

Second-step OLS estimates for domestic firms; regressions include industry, time, and region dummies; control variables included are downstream demand, industry competition, firm size, and firm age. Industry-level controls are defined according to the industry-level in the IO-tables. The dependent variable is first-differenced firm-level *TFP* based on first-step production function estimates by NACE 2-digit industry according to the indicated methodology on top of the columns. Results are based on the sample of firms with on average more than five employees. Standard errors in brackets are clustered at the industry-year level. ***/**/* denotes significance at 1/5/10 percent.

Table 4: FDI spillovers from all firms on Romanian manufacturing firms with at least five employees for the years 1996-2005 - vertical spillovers calculated using the non-zero-diagonal definition

| | (1) ACFva | (2) Lpva | (3) OP | (4) DPD | (5) FE | (6) TL |
|---|---|---|---|---|---|---|
| | **aggregated - NACE 2-digit** | | | | | |
| *horizontal* | 2.020** | 2.056** | 0.700* | 0.622* | 0.648* | 0.671* |
| | [1.002] | [1.006] | [0.382] | [0.374] | [0.378] | [0.375] |
| *backward* | 2.251 | 2.150 | 0.918 | 0.950 | 0.951 | 0.888 |
| | [1.964] | [1.969] | [0.710] | [0.695] | [0.712] | [0.706] |
| *forward* | -2.506 | -2.570 | -1.292* | -1.202* | -1.249* | -1.179* |
| | [1.856] | [1.843] | [0.669] | [0.661] | [0.660] | [0.666] |
| *n* | 73,255 | 78,710 | 96,681 | 96,728 | 96,728 | 96,728 |
| $R^2$ | 0.076 | 0.075 | 0.060 | 0.057 | 0.056 | 0.065 |
| | **detailed - Romanian NACE 3-digit equivalent** | | | | | |
| *horizontal* | 0.712 | 0.706 | 0.216 | 0.189 | 0.194 | 0.201 |
| | [0.497] | [0.502] | [0.190] | [0.189] | [0.189] | [0.187] |
| *backward* | 2.344** | 2.333** | 0.923*** | 0.944*** | 0.939*** | 0.934*** |
| | [1.004] | [1.011] | [0.323] | [0.321] | [0.325] | [0.321] |
| *forward* | -0.665 | -0.695 | -0.601 | -0.585 | -0.599 | -0.548 |
| | [1.169] | [1.170] | [0.418] | [0.417] | [0.414] | [0.416] |
| *n* | 73,255 | 78,710 | 96,681 | 96,728 | 96,728 | 96,728 |
| $R^2$ | 0.074 | 0.074 | 0.061 | 0.058 | 0.057 | 0.066 |

Second-step OLS estimates for domestic firms; regressions include industry, time, and region dummies; control variables included are downstream demand, industry competition, firm size, and firm age. Industry-level controls are defined according to the industry-level in the IO-tables. The dependent variable is first-differenced firm-level *TFP* based on first-step production function estimates by NACE 2-digit industry according to the indicated methodology on top of the columns. Results are based on the sample of firms with on average more than five employees. Standard errors in brackets are clustered at the industry-year level. ***/**/* denotes significance at 1/5/10 percent.

Table 5: FDI spillovers from all firms on Romanian manufacturing firms with at least five employees for the years 1996-2005 - vertical spillovers calculated using the non-zero-diagonal definition, correction for final uses.

| | (1) ACFva | (2) LPva | (3) OP | (4) DPD | (5) FE | (6) TL |
|---|---|---|---|---|---|---|
| | **aggregated - NACE 2-digit** | | | | | |
| *horizontal* | 2.045** | 2.079** | 0.702* | 0.625* | 0.651* | 0.674* |
| | [1.011] | [1.013] | [0.386] | [0.378] | [0.382] | [0.379] |
| *backward* | 3.232 | 3.120 | 1.008 | 1.092 | 1.066 | 0.997 |
| | [2.323] | [2.323] | [0.869] | [0.867] | [0.888] | [0.862] |
| *backward* | -2.568 | -2.532 | -0.238 | -0.372 | -0.304 | -0.288 |
| **intermed* | [4.887] | [4.896] | [2.025] | [1.995] | [2.040] | [1.989] |
| *forward* | -2.427 | -2.492 | -1.286* | -1.193* | -1.242* | -1.172* |
| | [1.832] | [1.820] | [0.664] | [0.654] | [0.654] | [0.660] |
| $n$ | 73,255 | 78,710 | 96,681 | 96,728 | 96,728 | 96,728 |
| $R^2$ | 0.076 | 0.076 | 0.060 | 0.057 | 0.056 | 0.065 |
| | **detailed - Romanian NACE 3-digit equivalent** | | | | | |
| *horizontal* | 0.690 | 0.685 | 0.215 | 0.187 | 0.192 | 0.199 |
| | [0.488] | [0.493] | [0.188] | [0.188] | [0.187] | [0.185] |
| *backward* | 3.165** | 3.110** | 0.956* | 0.990* | 0.994* | 0.986* |
| | [1.413] | [1.416] | [0.517] | [0.523] | [0.532] | [0.511] |
| *backward* | -1.931 | -1.833 | -0.080 | -0.111 | -0.135 | -0.126 |
| **intermed* | [2.643] | [2.663] | [1.026] | [1.013] | [1.036] | [1.003] |
| *forward* | -0.585 | -0.617 | -0.597 | -0.580 | -0.594 | -0.543 |
| | [1.150] | [1.151] | [0.412] | [0.411] | [0.408] | [0.410] |
| $n$ | 73,255 | 78,710 | 96,681 | 96,728 | 96,728 | 96,728 |
| $R^2$ | 0.075 | 0.074 | 0.061 | 0.058 | 0.057 | 0.066 |

Second-step OLS estimates for domestic firms; regressions include industry, time, and region dummies; control variables included are downstream demand, industry competition, firm size, and firm age. Industry-level controls are defined according to the industry-level in the IO-tables. The dependent variable is first-differenced firm-level *TFP* based on first-step production function estimates by NACE 2-digit industry according to the indicated methodology on top of the columns. Results are based on the sample of firms with on average more than five employees. Standard errors in brackets are clustered at the industry-year level. ***/**/* denotes significance at 1/5/10 percent.

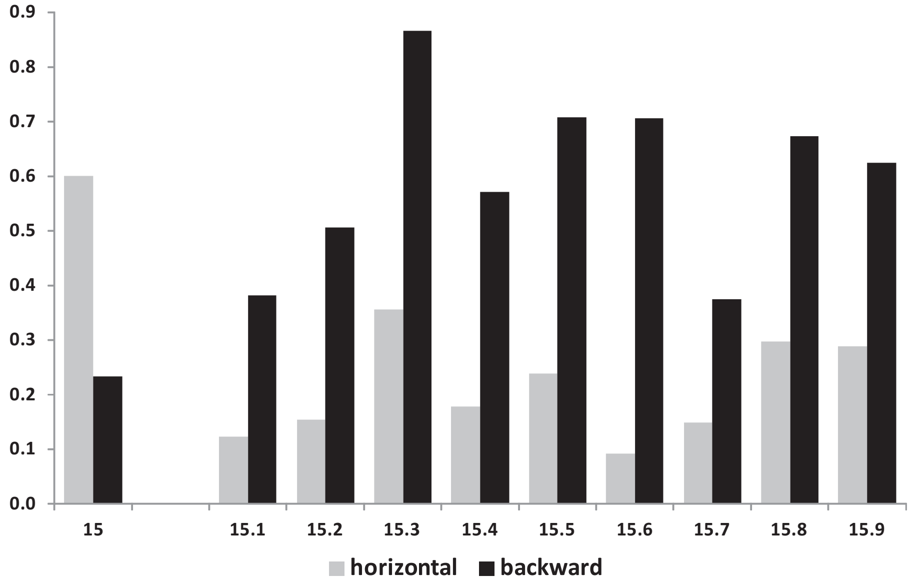


Figure 5: Contribution of 1996-2005 mean horizontal and backward spillovers to log $TFP$ ACF of domestic firms for NACE 2-digit industry "Manufacture of food products and beverages - 15" based on the ACF specification in Table 3 and its 3-digit sub-industries based on the ACF specification in Table 4.

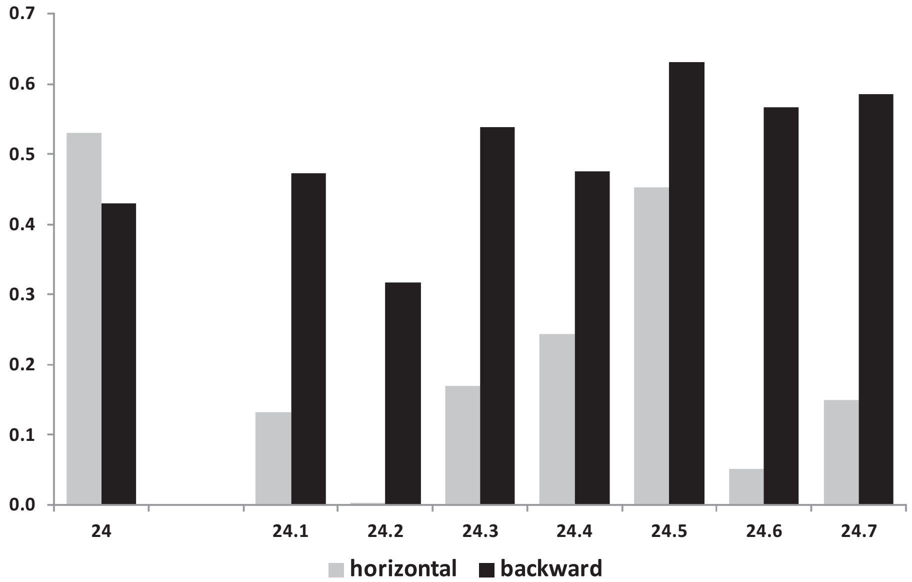


Figure 6: Contribution of 1996-2005 mean horizontal and backward spillovers to log $TFP$ ACF of domestic firms for NACE 2-digit industry "Manufacture of chemicals and chemical products - 24" based on the ACF specification in Table 3 and its 3-digit sub-industries based on the ACF specification in Table 4.

# Appendix A

| IO-code | Description | NACE rev.1.1 | | No. firms |
|---|---|---|---|---|
| | | 3-digit | 2-digit | 2005 |
| 18 | Meat production and processing | 15.1 | 15 | 603 |
| 19 | Processing and preserving of fish and fish products | 15.2 | 15 | 25 |
| 20 | Processing and preserving of fruits and vegetables | 15.3 | 15 | 123 |
| 21 | Production of vegetal and animal oil and fat | 15.4 | 15 | 68 |
| 22 | Production of milk products | 15.5 | 15 | 335 |
| 23 | Production of milling products, starch and starch products | 15.6 | 15 | 458 |
| 24 | Manufacture of fodder | 15.7 | 15 | 58 |
| 25 | Processing of other food products | 15.8 | 15 | 2675 |
| 26 | Beverages | 15.9 | 15 | 367 |
| 27 | Tobacco products | 16 | 16 | 17 |
| 28 | Textile industry | 17 | 17 | 1024 |
| 29 | Textile clothing | 18.2 | 18 | 2636 |
| 30 | Manufacture of leather and fur clothes | 18.1+18.3 | 18 | 35 |
| 31 | Footwear and other leather goods | 19 | 19 | 1082 |
| 32 | Wood processing (excluding furniture) | 20 | 20 | 1989 |
| 33 | Pulp, paper and cardboard; related items | 21.1+21.2 | 21 | 282 |
| 34 | Publishing, printing and reproduction of recorded media | 22 | 22 | 1016 |
| 35 | Coking | 23.1 | 23 | 1 |
| 36 | Crude oil processing | 23.2 | 23 | 27 |
| 37 | Processing of nuclear combustibles | 23.3 | 23 | - |
| 38 | Basic chemical products | 24.1 | 24 | 154 |
| 39 | Pesticides and other agrochemical products | 24.2 | 24 | 9 |
| 40 | Dyes and varnishes | 24.3 | 24 | 105 |
| 41 | Medicines and pharmaceutical products | 24.4 | 24 | 92 |
| 42 | Soaps, detergents, upkeeping products, cosmetics, perfumery | 24.5 | 24 | 88 |
| 43 | Other chemical products | 24.6 | 24 | 62 |
| 44 | Synthetic and man made fibres | 24.7 | 24 | 7 |
| 45 | Rubber processing | 25.1 | 25 | 117 |
| 46 | Plastic processing | 25.2 | 25 | 742 |
| 47 | Glass and glassware | 26.1 | 26 | 212 |
| 48 | Processing of refractory ceramics (excluding building items) | 26.2 | 26 | 104 |
| 49 | Ceramic boards and flags | 26.3 | 26 | 14 |
| 50 | Brick, tile and other building material processing | 26.4 | 26 | 79 |
| 51 | Cement, lime and plaster | 26.5 | 26 | 16 |
| 52 | Processing of concrete, cement and lime items | 26.6 | 26 | 254 |
| 53 | Cutting, shaping and finishing of stone | 26.7 | 26 | 94 |
| 54 | Other non-metallic mineral products | 26.8 | 26 | 42 |
| 55 | Metallurgy and ferroalloys processing | 27.1 | 27 | 26 |
| 56 | Manufacture of basic precious and non-ferrous metals | 27.2 | 27 | 19 |
| 57 | Other metallurgy products | 27.3 | 27 | 18 |
| 58 | Precious metals and other non-ferrous metals | 27.4 | 27 | 35 |
| 59 | Foundry | 27.5 | 27 | 122 |

| IO-code | Description | NACE rev.1.1 | | No. firms |
|---|---|---|---|---|
| | | 3-digit | 2-digit | 2005 |
| 60 | Metal structures and products | 28 | 28 | 2101 |
| 61 | Manufacture of equipment for producing/using of mechanical power | 29.1 | 29 | 108 |
| 62 | Machinery for general use | 29.2 | 29 | 172 |
| 63 | Agricultural and forestry machinery | 29.3 | 29 | 50 |
| 64 | Machine tools | 29.4 | 29 | 96 |
| 65 | Other machines for special use | 29.5 | 29 | 175 |
| 66 | Armament and ammunition | 29.6 | 29 | - |
| 67 | Labour-saving devices and domestic machinery | 29.7 | 29 | 39 |
| 68 | Computers and office means | 30 | 30 | 132 |
| 69 | Electric machinery and appliances | 31 | 31 | 348 |
| 70 | Radio, TV-sets and communication equipment and apparatus | 32 | 32 | 84 |
| 71 | Medical, precision, optical, watchmaking apparatus | 33 | 33 | 231 |
| 72 | Means of road transport | 34 | 34 | 209 |
| 73 | Naval engineering and repair | 35.1 | 35 | 198 |
| 74 | Production/repair of railway transport means and rolling equipment | 35.2 | 35 | 50 |
| 75 | Aircraft engineering and repair | 35.3 | 35 | 13 |
| 76 | Motorcycles, bicycles and other transport means | 35.4 | 35 | 7 |
| 77 | Furniture | 36.1 | 36 | 1438 |
| 78 | Other industrial activities | 36.2→36.6 | 36 | 280 |