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What Drives Trade-related R&D Spillovers? Decomposing Knowledge-diffusing Trade Flows

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What Drives Trade-related R&D Spillovers?

Decomposing Knowledge-diffusing Trade Flows

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Abstract

Our paper decomposes knowledge-diffusing trade flows and estimates their impacts separately. Overall, trade generates positive knowledge spillovers, but the effects of intra-industry trade are ambiguous. With regard to sectoral import penetration, we find that potential positive spillovers are dominated by negative competition effects. This, however, masks the significant positive spillover effects of intra-industry trade that corresponds to international outsourcing.

Keywords: R&D, trade, productivity, spillovers, competition

JEL: F20, O30, O40, D62

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1 Introduction

Since the seminal paper of Coe and Helpman (1995), the research on trade as a channel for knowledge diffusion has come a long way. The studies of Coe et al. (1997), Keller (1998), Franzen (1998), Keller (1999), Kao et al. (1999), Edmond (2001), Park (2004), Verspagen (1997) – to mention only a few – have completed the picture of trade as a channel for knowledge diffusion by using different estimation techniques, data and model variations to test for the sensitivity of the results. All of them arrive at the conclusion that *on average*, foreign R&D leads via trade to positive spillovers and thus increases productivity in the absorbing countries. What remained on the research agenda is the decomposition of the trade channel. With regard to foreign direct investment (FDI) Smarzynska Javorcik (2004) and Aitken and Harrison (1999) highlight the importance to differentiate between horizontal and vertical linkages. Their results suggest that while strong positive spillovers can be expected from vertical FDI, horizontal intra-industry FDI can have negative productivity effects through increased competition. With regard to international trade, however, the balance between spillovers and competition effects and the crucial role that different types of trade play as a transmission channel for knowledge has still not been analyzed.

The key contribution of the present note is to close this gap by decomposing the knowledge-diffusing trade channels and estimating their individual impacts on the output and productivity of the trading countries. Section 2 briefly describes our empirical model and data set, while Section 3 presents the empirical findings. Using industry-level data for seventeen OECD countries during the period 1973-2000, we confirm the results of previous studies, showing that trade on an aggregated level leads to positive knowledge spillovers. In a second step, we control for the effects of intra-industry trade, showing that at the sectoral level the negative competition effect dominates. However, by simultaneously controlling for outsourcing captured by imports of intermediate goods we show that the negative competition effect is the result of imported final goods while imported intermediate goods – which reflect international outsourcing – exert a positive productivity effect through knowledge spillovers. Finally, in Section 4, we draw some conclusions.

2 Empirical methodology and data

We assess the role of different trade channels by weighting the foreign R&D capital stock with three different weights corresponding to overall manufacturing imports, sectoral imports and sectoral outsourcing.

S^{fm} denotes the foreign capital stock (S^f) weighted by overall manufacturing imports:

$$S^{fm}_{ct} = \frac{m_{ct}}{Q_{ct}} \sum_{l \neq c} S^f_{lt}, \tag{1}$$

where m_{ct} denotes the sum of all imports into the manufacturing sector of country c in t and Q_{ct} denotes the gross domestic product of county c's manufacturing sector in t.

The sectoral import-weighted foreign R&D capital stock S^{fs} is constructed as:

$$S^{fs}_{cit} = \frac{m_{cit}}{Q_{cit}} \sum_{l \neq c} S^f_{lt}, \tag{2}$$

where m_{cit} denotes the sum of all imports of goods from industry i of country c in t and Q_{cit} denotes the gross domestic product of sector i in county c in t. Essentially

$\frac{m_{cit}}{Q_{cit}}$ corresponds to a simple sectoral import penetration measure.

Finally, we assess the role of the part of international trade, that can be seen as corresponding to international outsourcing. In a similar vein to Feenstra and Hanson (1999), we measure an industry's outsourcing intensity by utilizing the imported intermediate inputs from the same industry abroad, derived by combining input-output tables and trade data. S_{cit}^{fsint} denotes the foreign R&D capital stock weighted by sectoral outsourcing:

$$S_{cit}^{fsint} = \frac{\phi_{cit} * m_{cit}}{Q_{cit}} \sum_{l \neq c} S_{lt}^{f}, \tag{3}$$

where ϕ_{cit} denotes the share of imports of goods from industry i that are consumed by the respective domestic industry. In the framework of input-output tables $\phi_{cit} * m_{cit}$ corresponds to the main diagonal of an imported input use matrix.

Expanding on Coe and Helpman (1995) and Lichtenberg and van Pottelsberghe de la Potterie (1998) we specify the following model:

$$\begin{aligned} \ln Q_{cit} = {} & \alpha_i D^i + \alpha_c D^c + \beta_1 \ln S_{ct}^{d} + \beta_2 \ln S_{ct}^{fm} + \beta_3 \ln S_{ct}^{fs} + \beta_4 \ln S_{ct}^{fsint} \\ & + \beta_5 \ln K_{cit} + \beta_6 \ln L_{cit} + \beta_7 \ln M_{cit} + \alpha_t D^t + \nu_{cit}, \end{aligned} \tag{4}$$

where Q is output, S^d is the domestic R&D capital stock of the manufacturing sector and S^{fm}, S^{fs} and S^{fsint} represent the foreign R&D capital stock weighted as described above. L denotes labor, K physical capital, M material / intermediate inputs while D^i, D^c and D^t are full sets of sector, country, and time dummies. Subscripts i, c, and t denote sectors, countries, and years.

All stock variables are constructed using the perpetual inventory method with a depreciation rate of ten percent. The R&D capital stocks at time $t = 0$ were constructed using the standard procedure as described in Hall and Mairesse (1995).

We use industry level data on seventeen OECD countries in the time period 1973-2000.[1]

The estimations are carried out as FGLS, with a correction for panel-specific autocorrelation of the form AR(1), panel heteroscedasticity and a full set of sector, country, and time dummies. Unit root tests rejected the hypothesis of a unit root for all time series, which proved to be trend-stationary. After testing for the endogeneity of factor input, we found that the null hypothesis that inputs are exogenous cannot be rejected.[2]

3 Estimation results

We estimate Equation 4 in different steps. Column I of Table 1 shows the estimated coefficients for the basic model simply including the foreign knowledge capital stock weighted by aggregated manufacturing imports as in Equation 1. The coefficients on employment, material inputs and capital are statistically significant and have the expected positive sign. Furthermore, we confirm the results of former studies that manufacturing imports are indeed an important transmission channel for foreign knowledge.

Column II of Table 1 depicts the estimation results of the basic model augmented by the foreign knowledge capital stock weighted by sectoral imports as in Equation 2. Again aggregated manufacturing imports are a significant channel for knowledge spillovers. However, controlling for the effects of intra-industry trade as a potential

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[1] A detailed description of the data is given in a separate appendix available upon request.

[2] The results of the unit root and endogeneity tests are reported in a separate appendix available upon request.

channel for knowledge diffusion shows the importance of negative competition effects through sectoral import penetration. The marginal effect of foreign knowledge is thus the sum of these two effects, resulting in an output elasticity of two percent.

In a third model specification, we assess the role of international outsourcing as a specific form of intra-industry trade. This limits us to the data on those countries with available OECD input-output tables[3], which are the basis for the construction of industry-level outsourcing measures. We rerun the simpler model specifications with the reduced sample. Although spillover effects are somewhat smaller, we can generally confirm our previous findings in all specifications (see Columns III and IV). Column V of Table 1 reports the estimation results of the fully specified model (Equation 4) including the foreign knowledge capital stock weighted by intermediate imports as in Equation 3. The results show that intermediate goods imports (i.e. international outsourcing) act as a channel for knowledge diffusion, with the desired positive effects on sectoral output. Differentiation shows that a one percent rise in the foreign knowledge capital stock increases sectoral output by 0.9 percent. This effect is composed of a positive spillover effect of manufacturing imports of 2.6 percentage points, a negative competition effect through intra-industry trade of -1.8 percentage points and a positive spillover effect through international outsourcing of 0.1 percentage points.

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[3] Canada, Germany, France, Denmark, Italy, Japan, Netherlands, United Kingdom, USA.

4 Conclusions

In our search for trade-related knowledge spillovers we find that a decomposition of knowledge-diffusing trade flows adds to the existing studies some important aspects: first, we confirm the overall positive effect of trade as a channel of spillovers at the sectoral level. Second, controlling for the effects of knowledge diffusion through intra-industry trade, we find that positive spillovers are dominated by negative competition effects. Finally, taking the analysis a step further by additionally differentiating intra-industry trade with intermediate products (i.e. international outsourcing) as a potential channel for knowledge diffusion, we identify the expected positive knowledge spillovers.

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Table 1: Estimation results

ln Q dependent variable					
	I	II	III	IV	V
ln S^d	0,0430	0,0474	0,036	0,043	0,046
	[8.14]***	[8.88]***	[2.97]***	[3.49]***	[3.72]***
ln S^{fm}	0,0211	0,0329	0,013	0,028	0,026
	[4.29]***	[6.00]***	[1.66]*	[3.33]***	[3.05]***
ln S^{fs}		-0,0134		-0,018	-0,018
		[4.95]***		[4.46]***	[4.54]***
					0,001
					[1.97]**
ln K	0,0297	0,0276	0,018	0,013	0,014
	[9.27]***	[9.12]***	[3.33]***	[2.21]**	[2.54]**
ln L	0,1639	0,1573	0,175	0,164	0,165
	[35.06]***	[34.12]***	[22.06]***	[19.47]***	[20.26]***
ln M	0,7954	0,7931	0,790	0,790	0,789
	[212.86]***	[210.25]***	[146.13]***	[144.53]***	[143.22]***
Constant	0,6025	0,6704	0,835	0,957	0,905
	[7.14]***	[7.39]***	[4.68]***	[5.28]***	[4.97]***
Observations	3320	3320	1632	1632	1632
Number of groups	170	170	90	90	90

Remarks: Country-, industry- and time-specific effects are included and group wise jointly significant at the one-percent level.t-statistic in parentheses. ***, **, * significance at the 1%, 5% and 10% level.

Separate appendix

to the paper

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Not for publication!

Separate appendix

Data description

The estimations of the simple model specification have been carried out on the basis of data for ten manufacturing industries in the 17 countries Canada (CAN), Czech Republic (CZE), pre-unification (till 1990) West Germany (DEW), post-unification (1990 onwards) Germany (DEU), Denmark (DNK), Finland (FIN), France (FRA), Italy (ITA), Japan (JPN), South Korea (KOR), Netherlands (NLD), Norway (NOR), Polen (POL), Spain (ESP), Sweden (SWE), the United Kingdom (GBR) and the United States (USA). The data were taken from the OECD databases ANBERD and STAN and the IMF database IFS.

The time series are generally available for the years 1973 to 2001 in ISIC Rev. 3 classification. Due to data constraints, the length of the available time series differ across countries. The panel is therefore unbalanced.

When estimating the model including the outsourcing weighted R&D capital stock, data availability is considerably constrained. We combine OECD input-output tables with trade data. While data on international trade is readily available, input-output tables only exist for a subsample of countries namely Canada, Germany, Denmark, France, Italy, Japan, Netherlands, the United Kingdom and the USA. Coverage of time periods varies between countries. In general OECD input-output tables are at least available for one year in the early 1970's, one in the late 1970's, some year in the 1980's and one year in the late 1990's. On this basis, we construct the share of imports of goods from an industry i that is consumed by the respective industry for all years for which the data is available. Missing observations are then extrapolated by regressing the available data points on a linear time trend separately for each country. These shares are then combined with annual trade data to derive an industry's intermediate imports. An alternative strategy is to identify intermediate imports on the basis of the goods description in the standard international trade classification (SITC). However, although this generally works well at the aggregated country level, it is not feasible for assigning intermediate goods imports to a specific industry.

All data was deflated to constant 1995 prices using the OECD value-added deflator for the manufacturing sector and was then converted into USD using the exchange rates from 1995. To this end, Euro-data was converted back into national currency. From this data, output Q is measured as gross production. All stocks, i.e., the physical capital stock, the R&D capital stock and the FDI stocks, are calculated using the perpetual inventory method where a depreciation rate of ten percent is assumed. Labor L is measured as the number of employees, and material/intermediate inputs M are calculated as the difference between gross output and value added.

Estimation technique

The empirical assessment is based on the logarithmic form of the Cobb-Douglas production function developed above (see Equation (1)). The estimations have been carried out as FGLS, with a correction for panel-specific autocorrelation of the form AR(1), panel heteroscedasticity and a full set of sector, country, and time dummies.

Unit root tests rejected the hypothesis of a unit root for all time series used, thus showing that the time series are trend-stationary (see below).

The estimations have been carried out with fixed effects. The specification was furthermore supported by Hausman tests (not reported), which showed that the fixed sector, country, and time effects appear to be correlated with the explanatory variables. The estimations have therefore been carried out with a full set of sector, country, and time dummies. The latter set not only control for economy-wide exogenous shocks, but also guarantee that the time series are detrended.[1]

Furthermore, Lagrange multiplier (LM) tests (see Godfrey, 1988) based on residuals from eq. (1) reveal that ν_{cit} follows a panel-specific autoregressive process of order 1, i.e. $\nu_{cit} = \rho_1 \nu_{ci,t-1} + \varepsilon_{cit}$, with $\varepsilon_{cit} \sim N(0, \sigma^2)$. The Pagan-Hall statistic indicates heteroscedasticity in the estimated errors. Accordingly, the estimations have been carried out as FGLS with AR(1) and heteroscedasticity-corrected standard errors.

Finally, we have tested for the endogeneity of factor input. This issue arises in particular in firm- or plant-level productivity studies because firms might partly base their decision concerning the factor input combination on the observed total factor productivity. In this case, the error term and the contemporaneous levels of factor inputs would be correlated, leading to biased estimates of the coefficients. However, following Zellner et al. (1966) we argue that due to the aggregation of individual data, the industry-level output can be considered stochastic. For stochastic outputs, Zellner et al. (1966) show that OLS regressions of Cobb-Douglas production functions yield consistent estimates of the output elasticities. The null hypothesis that inputs are exogenous is not rejected when tested by the test statistic outlined in Baum, Schaffer and Stillman (2003).

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[1] Using a time trend for detrending does not alter the results. However, to also control for economy-wide exogenous macroeconomic shocks, we use time dummies instead of a time trend.

Unit root test

The panel is unbalanced since data are missing for a few sectors in some years. Thus, the Fisher method, which was proposed by Maddala and Wu (1999), appears suitable. It also has the benefit of flexibility regarding the specification of individual effects, individual time trends and individual lengths of time lags in the ADF regressions (Baltagi, 2001, p. 240). The P_λ-statistic is distributed chi-square with $2 \cdot N$ degrees of freedom, where N is the number of panel groups. As Table 1 shows, the tests do not indicate evidence of unit roots, either in the output series $\ln Q$ or in the factor input series $\ln K$, $\ln L$, $\ln M$, $\ln S^d$ or in the weighted foreign capital stock $\ln S^{fm}$,$\ln S^{fs}$,$\ln S^{fsint}$.

Table 1: Fisher unit root tests

Variable	P_λ-statistic	p-value
$\ln Q$	788.689	0.000
$\ln K$	461.267	0.000
$\ln L$	423.796	0.000
$\ln M$	765.341	0.000
$\ln S^d$	535.243	0.000
$\ln S^{fm}$	675.386	0.000
$\ln S^{fs}$	413.973	0.000
$\ln S^{fsint}$	235.625	0.003

Exogeneity tests

With exception of labour and intermediate/material inputs, all other production factors are stock variables. The latter have been constructed by using the perpetual inventory method with a constant depreciation rate of ten percent. This implies that depreciation of investments takes longer than 20 years and thus investments remain in the stock variable for that time. Thus, endogeneity is unlikely to be an issue for the stock variables used.

Therefore, the only suspicious variables are labour and intermediate/material inputs. To test for exogeneity of these two variables, we apply a General Method of Moments (GMM) regression using lagged values of labour and intermediate/material inputs as instruments as outlined in Baum et al. (2003). We prefer the use of GMM over instrumental variable (IV) estimation because the latter is not consistent in the presence of heteroskedasticity and autocorrelation. The results of the exogeneity test are reported in Tables 2 and 3 for the full and the reduced sample respectively. The hypothesis of exogeneity of the instrumented regressors cannot be rejected for all specifications.

Table 2: Exogeneity tests for *ln L* and *ln M* for full sample

Test of predictive power of instruments		
	ln L	*ln M*
$SheaPartialR^2$	0.7831	0.5285
Test of orthogonality of restricted fully efficient model		
Hansen J-Statistic	$Chi^2 = 4.336$	
	$P-val = 0.362$	
Test of orthogonality of unrestricted less efficient model		
Hansen J-Statistic	$Chi^2 = 0.310$	
	$P-val = 0.856$	
Test for exogeneity of regressors		
C-statistic	$Chi^2 = 4.026$	
	$P-val = 0.134$	

Table 3: Exogeneity tests for *ln L* and *ln M* for reduced sample

Test of predictive power of instruments		
	ln L	*ln M*
$SheaPartialR^2$	0.843	0.633
Test of orthogonality of restricted fully efficient model		
Hansen J-Statistic	$Chi^2 = 1.613$	
	$P-val = 0.806$	
Test of orthogonality of unrestricted less efficient model		
Hansen J-Statistic	$Chi^2 = 0.426$	
	$P-val = 0.808$	
Test for exogeneity of regressors		
C-statistic	$Chi^2 = 1.187$	
	$P-val = 0.552$	

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