Can trade hurt?
A follow-up on Samuelson's controversial paper

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Abstract

This paper puts Samuelson's (JEP, 2004) argument that technical progress of the trade partner may create net-losses for the home country to the empirical test. First we examine in a simple Ricardian model situations where the exchange of goods also constitutes a partial export of the technology used to produce these goods, i.e. knowledge diffusion. Within this framework Samuelson's Act II effect may occur. Secondly, based on industry data of ten manufacturing sectors of seventeen OECD countries for the period 1973 to 2000 we test if export and outward FDI are significant channels for knowledge diffusion. The estimations have been carried out using a feasible GLS (FGLS) estimator with a correction for panel specific first order autocorrelation and panel heteroskedasticity. Our results show that exports and outward FDI are significant channels for diffusion of domestic knowledge to trade partners and FDI receiving countries. Thirdly, as expected we find that this outflow of domestic knowledge has a negative impact on industry output of the source country.

Keywords: knowledge diffusion, foreign direct investment, outward FDI, productivity, competition
JEL: F10, F11, F14, O30.

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1 Introduction

The work by Samuelson (2004) has renewed the discussion that technological progress in the trade partner country may hurt the home country (Samuelson's Act II effect). Taken up by media and enriched with some annecdotical evidence on theft of intellectual property by trade partners, politicians, business people and ordinary citizens concluded that the negative impact of outward knowledge diffusion via trade might countervail the benefits from trade.

The heated public discussion leaves a mark that the phenomenon was discovered only recently. However, Samuelsons (2004) contribution links back to an important branch of international economics literature that deals with the interaction of trade and technological competition starting already in the seventies of the last century: Samuelson, 1977; Johnson and Stafford, 1993; Gomory and Baumol, 1997; Johnson and Stafford, 1997; Gomory and Baumol, 2000; Jones and Ruffin, 2005. What all these works have in common is that in one version or another, technological progress at the lower technology trade partner country may hurt welfare (usually measured as relative or real wages) of the technologically advanced home country, i.e. Samuelson's Act II type effects.[1]

While these papers generally pay little attention to the actual drivers for technological progress in the foreign country, a substantial literature on international knowledge diffusion has evolved in parallel, as summarised recently by Keller (2004). On the theoretical side, papers such as Helpman (1993) and Eaton and Kortum (2001, 2006) provide models which discuss the implications of international technology diffusion on the incentives to innovate, and the relationship with trade.[2] Along with the theoretical literature empirical studies generally acknowledge that trade is an important channel for the diffusion of foreign knowledge (Coe and Helpman 1995, Keller 1998, 1999, Frantzen 1998, Park 2004, Bitzer and Geishecker 2006 to mention only a few).[3] A related literature stresses the importance of foreign direct

[1]In fact many of these papers rather show when this type of effect does not occur. For example the Technology Transfer Paradox established by Jones and Ruffin, 2005, finds that when home loses an entire comparative advantage sector to foreign due to foreign's technological progress, home is actually better off. Only in the interim parameter range – where we have partial specialization – does Samuelson's Act II effect occur. For an illustrative account of an Act II type effect and under what conditions the effect vanishes see also Krugman (1996, chapter 4).

[2]This branch of literature, however, does not feature Act II type effects. On the contrary, for example Eaton and Kortum (2006) identify that the high research country may benefit from faster diffusion.

[3]We interpret the notion that imports contain knowledge in the broadest possible sense,

investment (FDI) as relevant channels of technology transfer. Multinationals' headquarters possess certain headquarter services or firm specific assets (technology) which are, at least partly, transferred to the affiliate abroad (e.g., Markusen, 2002). Local competitors may subsequently learn the technology through either imitation, movements of workers, or input-output linkages with multinationals (see Görg and Greenaway 2004 for a review).

However, thus far the focus of the empirical studies on international knowledge diffusion has been on the effects in the country receiving the knowledge spillover. Thus, it was tested which impact knowledge from foreign countries has on the output or productivity of the receiving country. Obviously, this method can not help answer the questions that emerged with Samuelson's (2004) paper: First, does trade in itself transfer domestic knowledge to trade partners? And second, does this outward-diffusion of knowledge hurt the sending country? While there is anecdotical evidence that knowledge might diffuse to trade partners[4] there is no evidence at all to answer the second question.

This is the starting point of our paper. First, we examine situations in which export activity does not only mean the exchange of goods but also constitutes a partial export of the technology used to produce these goods in a simple Ricardian model. In the presence of knowledge diffusion Samuelson's Act II effect can occur, and we determine the implied effects of this situation on home output. Second, based on industry data of ten manufacturing sectors of seventeen OECD countries for the period 1973 to 2000 we test if export and outward FDI are significant channels for outward-diffusion of domestic knowledge and which impact those knowledge spillovers have on the production of the sending country. The estimations have been carried out using a feasible GLS (FGLS) estimator with a correction for panel-specific first order autocorrelation and panel heteroskedasticity. Our results show that exports and outward FDI are significant channels for diffusion of domestic knowledge to trade partners and FDI receiving countries. We find that this outflow of domestic knowledge has a negative impact on industry output of the source country.

The next section presents a formalization of Samuelson's Act II effect, based on Johnson and Stafford, 1993, and provides some first insights into situations when export activity also constitutes knowledge diffusion. Section 3 describes our empirical approach and the used data, Section 4 discusses the estimation results and Section 5 concludes.

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ranging from actual backwards engineering of products to the wider information contained in the fact that import activities can establish the existence of domestic demand for a certain product, etc.

[4]Cf. Maskus 2000, and many other reports.

2 A simple model

Consider a simple Ricardian two country world, where home and foreign (denoted by an asterisk) each have the ability to produce three goods $j = A, B, C$. Each sectors' output (Q_j, Q_j^*) is a function of the amount of labor (L_j, L_j^*) used – assuming labor market clearing $(\sum L_j = L, \sum L_j^* = L^*)$ – and a sectorial productivity parameters (λ_j, λ_j^*), e.g. $Q_j = \lambda_j L_j, j \in \{A, B, C\}$ and similarly for the foreign country. For the sake of clarity we assume that home has an absolute advantage in all sectors throughout, namely $\lambda_j > \lambda_j^*, j \in \{A, B, C\}$, and thus technology transfer – or rather knowledge diffusion – can only occur from home to foreign.

Both countries display identical Cobb-Douglas utility functions

$$U(D_A,D_B,D_C) = D_A^{\alpha} D_B^{\beta} D_C^{\gamma} \quad , \quad U^*(D_A^*,D_B^*,D_C^*) = D_A^{*\alpha} D_B^{*\beta} D_C^{*\gamma} \ , \tag{1}$$

where D_j and D_j^* represent consumption of good j in home and foreign respectively, and where $\gamma = 1 - \alpha - \beta$.

We consider two time periods $(0, 1)$ where in the initial period, trade patterns feature full specialization and home has a comparative advantage in two sectors, namely $\frac{\lambda_{j,0}}{\lambda_{C,0}} > \frac{\lambda_{j,0}^*}{\lambda_{C,0}^*}, j \in \{A, B\}$, and accordingly foreign has a comparative advantage in sector C. In period 1, in contrast, some knowledge diffusion in sector B has occurred and hence a situation of partial specialization may arise in the sense that both home and foreign may engage in the production of good B.

If partial specialization in period 1 occurs, it will be driven by an increase in $\lambda_{B,1}^*$ compared to $\lambda_{B,0}^*$. In particular, we postulate knowledge diffusion to take place such that $\lambda_{B,1}^* = max\{\theta\lambda_{B,0}, \lambda_{B,0}^*\}$, where $\theta < 1$, measures the extent to which technology spills over – for example via the export activity of the home country in period 0. Hence we have trade and technological competition. Time subscripts are omitted where unnecessary.

Under the assumption of perfect competition and constant returns to scale, world market prices P_j are equal to marginal (and average) costs, such that in period 0, we have $P_A = \frac{w}{\lambda_A}, P_B = \frac{w}{\lambda_B}$ and $P_C = \frac{w^*}{\lambda_C^*}$, where w and w^* are the domestic and foreign wage rates respectively.

Full employment and income - expenditure clearing implies for the foreign country $w^* L^* = P_C Q_C = \gamma E$, and for the home country $wL = P_A Q_A + P_B Q_B = (\alpha + \beta)E$, where E is the total world expenditure. Accordingly, relative wages in the initial period are

$$\frac{w_0}{w_0^*} = \frac{1-\gamma}{\gamma} \frac{L^*}{L} \ . \tag{2}$$

A Samuelson Act II type effect is most clearly observed in terms of real – not relative – wages. In order to calculate real wages we compose the common world price index which, given the above assumptions, is the geometric mean of commodity prices, $P = P_A^\alpha, P_B^\beta, P_C^\gamma = \frac{w^{1-\gamma} w^{*\gamma}}{\lambda_A^\alpha \lambda_B^\beta \lambda_C^{*\gamma}}$. Now domestic real wages $r = \frac{w}{P}$, which are our measure of welfare for the home country, can be expressed, using (2), as

$$r_0 = \left(\frac{1-\gamma}{\gamma}\frac{L^*}{L}\right)^\gamma \lambda_A^\alpha \lambda_B^\beta \lambda_C^{*\gamma} \, , \tag{3}$$

and for the foreign country – based on the same world price index – one finds

$$r_0^* = \left(\frac{\gamma}{1-\gamma}\frac{L}{L^*}\right)^{1-\gamma} \lambda_A^\alpha \lambda_B^\beta \lambda_C^{*\gamma} \, . \tag{4}$$

Next consider period 2. Without technology spillover (small θ) we have $\lambda_{B,1}^* = \lambda_{B,0}^*$, and accordingly full specialization continious along the same patterns established in period 0. However, for a sufficient degree of knowledge diffusion the increase in $\lambda_{B,1}^*$ could ensure that the foreign country finds it worthwhile to start production of good B. Partial specialization occurs once the ratio of foreign productivity on the good that is potentially produced by both countries to its comparative advantage good exceed the price ratio of the comparative advantage good to the partial specialization good. Formally, partial specialization arises once $\frac{\lambda_{B,1}^*}{\lambda_C^*} > \frac{P_C}{P_B}$. Similarly, once $\frac{\lambda_B}{\lambda_A} < \frac{P_A}{P_B^*}$, home will cease its production of B and we return to a situation of full specialization, albeit now foreign supplies both the B and the C good. Setting prices and the relative wage expression in the above condition yields the following result. Partial specialization in period 1 occurs if

$$\frac{1-\alpha}{\alpha}\frac{L}{L^*} = \bar{\theta} > \theta > \underline{\theta} = \frac{\gamma}{1-\gamma}\frac{L}{L^*} \, . \tag{5}$$

In the case when $\theta < \underline{\theta}$ we still have full specialization replicating period 0, and in the case where $\theta > \bar{\theta}$ full specialization with reversed roles for home and foreign is obtained. It is easily verified that $\bar{\theta} > \underline{\theta}$ for $\beta > 0$, thus a zone of partial specialization does exist. Furthermore, notice that the lower threshold $\underline{\theta}$ becomes lower, thus partial specialization becomes more likely, the larger the foreign country is and the smaller the global preferences for the foreign comparative advantage good is (smaller γ). Similarly, the upper threshold $\bar{\theta}$ increases, thus full reversal of roles becomes less likely, if the home country is larger and if the global preferences for home's comparative advantage good is smaller (smaller α). Put differently, the more important the B good is in global demand, the larger the zone of partial specialization, where neither country wants to give up production of the good in question.

The effect on the real wage rates of both countries, should (5) be fulfilled, can be determined as follows: Intra-country intra-sectoral labour mobility ensures wage equalization within each country, and accordingly $w_1 = \lambda_A P_A = \lambda_B P_B$ and similarly $w_1^* = \lambda_C^* P_C = \lambda_{B,1}^* P_B *$. International price equalization results then in the new wage ratio

$$\frac{w_1}{w_1^*} = \frac{\lambda_B}{\lambda_{B,1}^*} = \frac{1}{\theta}\ , \tag{6}$$

which only depends on relative productivity and thus the extend to which technology spills overs. Based on (6) the real wages under partial specialization become:

$$r_1 \;=\; \theta^{-\gamma}\,\lambda_A^{\alpha}\lambda_B^{\beta}\lambda_C^{*\gamma}\ , \tag{7}$$

$$r_1^* \;=\; \theta^{1-\gamma}\,\lambda_A^{\alpha}\lambda_B^{\beta}\lambda_C^{*\gamma}\ . \tag{8}$$

Comparison of the home country's real wage from (3) with that derived in (7), yields that $r_1 < r_0$ as long as $\theta > \frac{\gamma}{1-\gamma}\frac{L}{L^*}$, which it exactly the condition for partial specialization ($\theta > \underline{\theta}$) laid out in (5).

The following results (replicating Samuelson's Act II) have thus been derived. First, with sufficient technological spillover from the home to foreign country, home welfare is reduced both absolutely and relatively in the case where partial specialization occurs. This effect occurs, even though the foreign technology is strictly less than the home technology also after spillover ($\theta < 1$). Second, inspection of (7) and (8), discloses, that $\frac{\partial r_1}{\partial \theta} < 0$ and $\frac{\partial r_1^*}{\partial \theta} > 0$; thus, any further spillovers of technology from home to foreign (higher θ) has opposing effects on home and foreign. Improvements in the foreign technology in the B sector increase the foreign real wage but decrease the home real wage, and thus benefits foreign but hurts home. In contrast, notice that in the real wage expressions of period 0, technology advances in either country benefitted both countries. In particular $\frac{\partial r_0}{\partial \lambda_B} > 0$ and $\frac{\partial r_0^*}{\partial \lambda_B} > 0$, which will of cause also be the case once roles are reversed, and foreign is – after a sufficient increase in λ_B^* as implied in (5) – the sole producer of B.

The comparative statics of the various effects that are at work can also be seen when defining from the condition $r_0 > r_1$ or equivalently $\theta > \underline{\theta}$ in (5) the function $f = \frac{\gamma}{1-\gamma}\frac{L}{L^*\theta}$, which for $f < 1$ implies that the Samuelson's Act II does occur. Thus an increase in f makes a combination of trade and knowledge diffusion less problematic, while a decrease in f may cause welfare reductions. Immediately it can be seen that a larger size of the home country reduces the risks of harmful trade in the presence of knowledge diffusion, while a larger size of the foreign country, a larger spillover of technology (larger θ) and a smaller world preference for the comparative advantage good of the foreign country (lower γ) all exacerbate the problem. In particular, the last force is worth pointing out, since it implies that once foreign is stuck with a relatively unattractive good, its willingness to start producing and thus generating partial specialization in good B is much larger, i.e. in this case foreign will launch a production of B even though its absolute technology level $\lambda^*_{B,1}$ is significantly lower than that of home.

Finally, and important in view of our empirical investigation, we can examine the implications of the above model for home output in the B industry. Under full specialization we have $Q_{B,0} = L\lambda_B \left(\frac{\beta}{\alpha+\beta}\right)$ in period zero. While in period 1 under partial specialization we have:

$$Q_{B,1} = L\lambda_B \left(1 - \alpha \left(1 + \theta \frac{L^*}{L}\right)\right) . \quad (9)$$

Immediately it can be seen that a larger degree of knowledge diffusion (larger θ) and a larger relative size of the trade partner both lead to a reduction in home's period 1 output in sector B, given that partial specialization occurs. Furthermore, when we replace θ in (9) with $\phi\underline{\theta}$, such that – following from (5) – for $\phi > 1$ we are in situations of partial specialization, home's sector B output becomes $Q_{B,1} = L\lambda_B \left(\frac{\beta+(1-\phi)\gamma\alpha}{\alpha+\beta}\right)$. Thus, in this case, home's period one output in the B sector, where knowledge diffusion may have triggered partial specialization, is clearly less than $Q_{B,0}$ for all $\phi > 1$, and falls in γ, i.e. the world preference for foreign's initial comparative advantage good. Accordingly, within this framework a Samuelson Act II type effect – expressed in real wage terms – goes hand in hand with a reduction in home output of the good in question.

3 Empirical evaluation, estimation approach and empirical data

Technological progress of the trade partner can result from different factors, e.g. own R&D, learning by doing. However, one argument often cited in the above mentioned debate is knowledge spillovers (e.g. Samuelson 2004, p. 145), i.e. knowledge absorbed from imported goods is used in future competition against the trade partner. Unfortunately, thus far knowledge spillovers have only been studied as an input factor on the side of the spillover receiving industries or countries (e.g. Keller 2004). Our paper takes another approach and tests the hypothesis that outward diffusion of domestic knowledge might be harmful to the sender of the knowledge spillover. As illustrated in Section 2, such knowledge diffusion might result in a Samuelson Act II effect.

As it is know from previous studies foreign knowledge diffuses via imports and FDI into a country (e.g. Coe and Helpman 1995, van Pottelsberghe de la Potterie and Lichtenberg 2001). However, to the best knowledge of the authors it has not been analysed if there is any evidence on outward-diffusion of domestic knowledge and its impact on output. To test both aspects empirically – and controlling simultaneously for incoming spillovers – we estimate the following transformed Cobb-Douglas production function

$$\begin{aligned} ln\ Q_{jct} &= \beta_1 \ln K_{jct} + \beta_2 \ln L_{jct} + \beta_3 \ln M_{jct} + \beta_4 \ln RDS_{jct} \\ &+ \beta_5 \ln RDED_{jct} + \lambda \ln RDF_{ct} + \tau \ln EDS_{jct} \\ &+ \sigma \ln FDS_{jct} + \nu_{jc} + \iota_t + \epsilon_{jct} \end{aligned} \quad (10)$$

where Q is gross production and K, L, M are the standard production factors capital, labour and materials, respectively. These data are constructed at industry level from the OECD STAN database.[5] The capital stock is calculated using the perpetual inventory method and investment data, assuming a ten percent depreciation rate. L is the number of employees and M is measured as the difference between gross output and value added.[6]

RDS, $RDED$ and RDF are proxies for the sectoral R&D capital stock in country c, the external domestic R&D capital stock in country c (excluding sector j) and the R&D capital stock abroad (excluding country c), respectively. The variables are calculated using data from the OECD ANBERD database. Stocks are calculated using the same approach as for the physical capital stock.[7] Variable $RDED$ is constructed summing up all sectoral R&D capital stocks within a country excluding sector j. It captures knowledge spillovers within a country. The RDF variable is calculated as the sum of all R&D capital stocks in OECD countries apart from country c and is included to capture international knowledge spillovers through R&D activity abroad. Van Pottelsberghe de la Potterie and Lichtenberg (2001) and Coe and Helpman (1995) weight the foreign R&D stock using either FDI or trade data, in order to capture knowledge spillovers transmitted particularly through these channels. By contrast, as proposed by Keller (1998) and Mohnen (1996) we

[5] A detailed description of all data used in the estimations is given in the appendix.

[6] Note that materials include imported intermediate inputs.

[7] The R&D capital stocks at time $t = 0$ were constructed using the standard procedure as described in Goto and Suzuki (1989) or Hall and Mairesse (1995). An alternative approach for the construction of R&D capital stocks is pointed out by Bitzer (2005).

do not place any restrictions in terms of weights on RDF, thereby allowing for a general effect of all R&D undertaken abroad on domestic production.

Variables EDS and FDS are export driven spillovers and FDI driven spillovers, respectively. Inspired by the approach of Coe and Helpman (1995) and the extension of Lichtenberg and van Pottelsberghe de la Potterie (1998) EDS is constructed as the sectoral R&D capital stock multiplied with the sectoral export share. Similarly, FDS is constructed by multiplying the sectoral R&D capital stock with the total outward FDI capital stock over total domestic capital stock.

While the expected signs of the coefficients for the traditional inputs – physical capital, labour, materials, domestic R&D – are straightforward positive, the expected coefficients for the other variables warrant some discussion. Turning first to the expected signs of the external domestic and the foreign R&D capital stock variables both a positive as well as a negative sign are plausible. A positive sign of $RDED$ (RDF) indicates that on average a sector (country) benefits via knowledge spillovers from R&D carried out in other sectors (countries). A negative relationship between $RDED$ (RDF) and industry total factor productivity (TFP), on the other hand may suggest that R&D carried out in other sectors (countries) has increased the competitiveness of (foreign) competitors. This may lead to reductions in output as consumers prefer the competitors' products with negative consequences for domestic productivity.

Coming to the variables of particular interest to our paper the export driven (EDS) and FDI driven spillovers (FDS) both positive and negative signs can plausibly be explained. A significant negative sign of EDS (FDS) indicates that outward domestic knowledge diffusion takes place via trade (FDI) and has a negative impact on domestic output, e.g. a situation that would ocuur under a Samuelson's Act II effect. On the other hand both variables might also show significant positive signs indicating that countries benefit in terms of increased domestic output from outward knowledge diffusion – via exports or FDI – through outsourcing or technology sourcing.

The production function estimation includes fixed effects and time dummies. The estimations have been carried out using a feasible GLS (FGLS) estimator with a correction for panel specific first order autocorrelation and panel heteroskedasticity, as tests based on residuals from equation (1) indicate that the error term follows an autoregressive process of order 1.[8]

For firm or plant level productivity studies it is frequently argued that

[8]As a robustness check and accounting for possible small sample problems as pointed out be Beck and Katz (1995) we also ran regressions using an OLS with panel corrected standard errors, correction for panel specific first order autocorrelation and panel heteroskedasticity arriving at the same results as reported below.

factor inputs should be considered endogenous. This is because firms/plants may observe TFP at least partly which, in turn, may influence the choice of factor input combinations in the same period. Hence, there would be a correlation between the error term and the contemporaneous levels of factor inputs, leading to biased estimates of the coefficients.[9] However, following Zellner et al. (1966) one could argue that output at the industry level is stochastic, as the data for individual plants/firms are aggregated up. For the case that output is stochastic Zellner et al. (1966) show that OLS regressions of a Cobb-Douglas production function yields consistent estimates of the output elasticities. However, to be sure, we perform a test for endogeneity of inputs using the approach outlined by Baum, Schaffer and Stillman (2003). The results, which are reported in the appendix, indicate that we cannot reject the hypothesis of exogeneity of the regressors.

4 Estimation results

Table 1 presents the results of estimating three specifications of equation (1) using FGLS. In Column I we report the results of a standard model specification known from the spillover literature (e.g. Coe and Helpman 1995) including the standard input factors capital, labour, materials as well as a sectoral, an external domestic and a foreign R&D capital stocks. The coefficients for input factors capital, labour and materials show the expected positive significant signs which survive all model specifications. Furthermore, the coefficients of the external domestic and foreign R&D capital stocks confirm the results of former studies, i.e. showing the existence of positive knowledge spillovers both between domestic sectors and from foreign countries. As in the case of the traditional inputs, the coefficients of the external domestic and foreign R&D capital stocks remain positive and significant throughout all model specifications.

Coming to the coefficient of the sectoral R&D capital variable we find a highly significant but negative coefficient implying that R&D hurts the own production. A result which has not been reported by any study before.

[9] See, for example, Olley and Pakes (1996) and Levinsohn and Petrin (2003) for discussions of the problem and solutions for analyses using micro level data.

Table 1: FGLS Estimation Results

Indep. var.	**I**	**II**	**III**
	dependent variable is $\ln Q$		
$\ln RDS$	-0.0108***	0,0027	0.0144***
	[0.0017]	[0.0031]	[0.0038]
$\ln RDED$	0.0476***	0.0477***	0.0539***
	[0.0040]	[0.0040]	[0.0043]
$\ln RDF$	0.0580**	0.0792***	0.0671***
	[0.0227]	[0.0232]	[0.0234]
$\ln EDS$		-0.0134***	-0.0146***
		[0.0026]	[0.0026]
$\ln FDS$			-0.0084***
			[0.0018]
$\ln K$	0.0418***	0.0429***	0.0364***
	[0.0035]	[0.0035]	[0.0036]
$\ln L$	0.1406***	0.1378***	0.1403***
	[0.0056]	[0.0057]	[0.0059]
$\ln M$	0.7941***	0.7913***	0.7925***
	[0.0037]	[0.0037]	[0.0038]
Wald χ^2 (df)	1.10e+09 (204)	1.12e+09 (205)	7.10e+08 (206)
p-value Wald χ^2	0.0000	0.0000	0.0000
Obs.	3192	3192	3192
Number of groups	170	170	170

Remarks: Fixed effects and time dummies are included but not reported and groupwise significant at the one-percent level. Consistent standard errors in parentheses. ***, **, * indicate a significance at the 1%, 5% and 10% levels, respectively.

However, pushing the analysis a step further we include the export driven spillover variable into the model (Column II). It turns out that the coefficient is highly significant and negative. This implies – as expected – that exports act as a channel for outward diffusion of domestic knowledge and obviously this knowledge transfer is accompanied by a reduction in domestic output, which could be an indicator for the presence of Samuelson Act II type situations. Furthermore, the introduction of the export driven spillover variable renders the coefficient of the sectoral R&D capital stock insignificant. Thus, the coefficient of the sectoral R&D capital stock in Column I was dominated by the negative impact of the export driven spillover.

Finally, by introducing the FDI driven spillover variable we take into consideration that outward FDI might also act as a channel for outward diffusion of domestic knowledge. The results reported in Column III show that our suspicion was justified as the coefficient turns out to be highly significant. Like in the case of the export driven spillover the impact of the FDI driven spillover on domestic output is negative.

Surprisingly, with the introduction of the FDI driven spillover variable the coefficient for sectoral R&D capital stock becomes highly significant and positive. Thus, in the reduced model specification (Column I) the sectoral R&D capital stock variable obviously captured the negative effects of outward diffusion of domestic knowledge.

5 Conclusion

Our paper analyses theoretically and empirically if under certain circumstances trade might be harmful for the home country. In the theoretical part we illustrate this notion (Samuelson's, 2004, Act II effect) in a simple Ricardian model, where we examine the effects from foreign gaining a fraction of home's technology, on home welfare and on home output in the industry where the knowledge diffusion takes place. In the empirical part we test if exports and outward FDI are significant channels for outward knowledge diffusion. Both are channels that have frequently been pointed at in the debate that followed after Samuelson's (2004) arguments. Estimations based on industry data of ten manufacturing sectors of seventeen OECD countries for the period 1973 to 2000, show that on average both exports and outward FDI act as a channel for outward knowledge diffusion causing a decrease of domestic production.

Although the empirical evidence indicates that outward diffusion of domestic knowledge is on average harmful for the spillover sending country, the question remains, what the alternative no-trade benchmark would look like. Or put differently, even though the present paper has established negative effects stemming from outward knowledge diffusion, the alternative – autarky existence – is hardly a preferable situation. If anything, the present paper has shown that the impact of outward knowledge diffusion from trade and FDI activity and their interaction with Samuelson Act II type effects deserve further investigation.

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Appendix

Data description

The estimations 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 (1991 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 annual time series are 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.

The data was deflated to constant prices of 1995 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.

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. Another benefit of it is its 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 A1 shows, the tests do not indicate evidence of unit roots, either in the output series $\ln Q$ or in the factor input series $\ln K$, $\ln L$, $\ln M$, $\ln RDD$, $\ln RDF$, $\ln IDI$, or $\ln ODI$.

Table A1: Results for the Fisher-type Unit Root Test for Panel Data

Variable	P_λ-statistic	p-value
$\ln Q$	615.74282	0.000
$\ln K$	469.90825	0.000
$\ln L$	502.01711	0.000
$\ln M$	511.05298	0.000
logw	665.75002	0.000
logwexport	611.21475	0.000
logwfdiout	550.91663	0.000

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 used stock variables.

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. We prefer the use of GMM over instrumental variable (IV) estimation because the latter is not consistent in the presence of heteroskedasticity. As pointed out in the main text the latter is an issue in our data. The results of the exogeneity tests are reported in Table A2. In all cases the hypothesis of exogeneity of the suspicious regressors cannot be rejected.

Table A2: Exogeneity tests for *ln L* und *ln M*

Test statistic	**Table 1**		
	I	**II**	**III**
Test of predictive power of instruments			
Instruments *ln L*			
F-Test	23.59	23.86	51.20
P-value	0.0000	0.0000	0.0000
Instruments *ln M*			
F-Test	12.62	13.97	25.67
P-value	0.000	0.0000	0.0000
Test of orthogonality of instruments			
Hansen J-Statistic	3.184	4.645	10.174
P-value	0.5275	0.3257	0.1175
Test of orthogonality of unrestricted model			
Hansen J-Statistic	2.645	3.897	7.767
P-value	0.2664	0.1425	0.1005
Test for exogeneity			
C-statistic	0.538	0.748	2.407
P-value	0.7640	0.6881	0.3001
Exogeneity rejected	no	no	no