KU LEUVEN

FACULTY OF ECONOMICS AND BUSINESS

Sources of spillovers for imitation and innovation

Riccardo Cappelli, Dirk Czarnitzki and Kornelius Kraft

MSI_1309

Sources of spillovers for imitation and innovation[1]

- A revised version of this paper is forthcoming in *Research Policy* -

Riccardo Cappelli [a], Dirk Czarnitzki [b, d, e] and Kornelius Kraft [c, e]

a) Utrecht University, Faculty of Geosciences
b) KU Leuven, Dept. of Managerial Economics, Strategy and Innovation
c) TU Dortmund, Faculty of Economics
d) Centre for R&D Monitoring (ECOOM) at KU Leuven
e) Center for European Economic Research (ZEW), Mannheim

July 2013

Abstract

We estimate the effect of R&D spillovers on sales realized by products new to the firm (imitation) and new to the market (innovation). It turns out that spillovers from rivals lead to more imitation, while inputs from customers and research institutions enhance original innovation.

Keywords: innovation, imitation, spillovers

JEL-Classification: L12, O31, O32

Address:	Riccardo Cappelli	Dirk Czarnitzki	Kornelius Kraft
	Utrecht University	KU Leuven	Technical University of Dortmund
	Department of Economic Geography	Dept. of Managerial Economics, Strategy and Innovation	Dept. of Economics
	Heidelberglaan 2	Naamsestraat 69	Vogelpothsweg 87
	3584 CS Utrecht	3000 Leuven	44227 Dortmund
	The Netherlands	Belgium	Germany
Phone:	+31 030 253 2767	+32 16 326 906	+49 231 755 3152
E-Mail:	r.cappelli@uu.nl	dirk.czarnitzki@econ.kuleuven.be	Kornelius.Kraft@tu-dortmund.de

[1] We are grateful to the MIP team at the Centre for European Economic Research (ZEW) for providing the survey data.

1 Introduction

Spillovers of technological activity are a highly discussed issue in economics. Applications include economic growth (e.g., Romer, 1986), R&D incentives (e.g. Geroski et al., 1993, Hanel and St-Pierre, 2002, Cohen and Levinthal, 1989), R&D alliances (Caloghirou et al., 2001) or joint ventures (d'Aspremont and Jaquemin 1988, De Bondt 1996), respectively. The relevance in business practice is clearly demonstrated by Mansfield (1985) who reports how fast information concerning development decisions and information on the nature and operation of products and processes leaks to competitors.

In studies on firm-level productivity, spill-overs are typically modeled by including the sum of R&D of firms in the same industry, and sometimes R&D in other than the corresponding firm's industries in a regression. These measures have some shortcomings like the implicit limitation to a certain geographic area. Moreover, such studies account for spillovers from rivals (R&D in the same industry), or firms in other industries (see e.g. Hall et al., 2010, for a survey). The conventional measures by construction assume that recipients of spillovers all utilize them to the same extent as only one coefficient can be estimated for each variable. In addition, firms in other industries may either be suppliers (upstream firms) or customers (downstream firms). Spillovers from customers versus suppliers may differ significantly with respect to their contribution towards innovation.

Several studies also include the effect of research institutions, usually universities. This research is mainly interested in the effect of spillovers resulting from regional association or explicit cooperation with universities. The effect is mostly estimated by mean of a knowledge production function with patents, innovation counts or growth of total factor productivity as the endogenous variable.[2]

Although it is well known that spillovers will not only stimulate innovation but also induce imitation, the latter effect is mostly neglected. The econometric studies usually explain an indicator for innovativeness like R&D expenditures, the number of patents or innovation counts, but a variable standing for imitation is rarely applied as such information is hard to come by. However it is well known that information leaks out by informal communication or that scientists are poached by competing firms.

The view concerning spillovers inducing innovation and imitation is quite different. Innovation is usually positively valued as the knowledge in the economy increases. However if imitation is induced, copying innovations developed by others will usually be cheaper than executing own innovative activity. As a consequence the imitator has lower overall costs and can outbid rivals, which in turn negatively affects the incentives to execute R&D in the first place. Therefore spillovers leading to imitations might be negatively assessed, although total costs in an economy are lowered. The reason for a sceptical view is the dampening effect on incentives to perform R&D if the "input" comes for free from outside. This in turn affects the whole economy and is the basic reason for existence of the patent system

In this paper, we propose the use of survey measures that overcome the limitations of the 'traditional' spillover measures as discussed above. In addition, we distinguish the importance of spillovers for two types of innovative activitiy, i.e. original innovation based on own inventive activity versus imitation, and argue that heterogeneous effects can be expected by the source of the spillover. This differentiation is particularly of interest as we are able to distinguish between the sources of spillovers. The data includes information on whether the spillovers come from competitors, customers, suppliers or research institutions. This may be important as information from some sources may well be beneficial for imitation, but less for innovation. Possible examples are inflows from competitors. Other knowledge flows may in contrast stimulate innovative activity, for instance spillovers coming from research institutions. As Mansfield (1998) states, about 15% of new products in seven US industries in the period 1986-1994 and 11% of new processes could not have been developed in the absence of recent academic research.

---

[2] Examples of this kind of research include Jaffe (1989), Audretsch and Feldman (1996), Audretsch et al. (2005), Ponds et al. (2010).

2 Theoretical Considerations on the Effects of Spillovers

Spillovers are highly important in practice. According to Mansfield (1985) information on development decisions leaks within 12 to 18 months to competitors and information on the the exact operation of products and processes reaches rivals within 12 to 15 months.

The importance of spillovers is also reflected in the many applications in economics and these reflect the importance of this topic. One example is endogenous growth theory (Grossman and Helpman 1991) where knowledge produced by a company enhances productivity industrywide and is thus not subject to decreasing returns. Many microeconomic contributions consider how spillovers determine companies' behavior. By affecting profitability, incoming and outgoing spillovers cleary influence the incentives to engage in R&D projects (e.g. Geroski et al., 1993, Hanel and St-Pierre, 2002, Czarnitzki and Kraft, 2012). This in turn stimulates the formation of alliances in form of research joint ventures (d'Aspremont and Jaquemin, 1988, de Bondt 1996). Spillovers can be regarded as positive externalities and this is an argument in favour of subsidization of R&D efforts (Arrow, 1962).

Spillovers between firms

Spillovers are typically seen as core in the process of knowledge diffusion. One view on knowledge diffusion is that this is a free input which serves for imitation of innovations developed by competitors. Imitation will usually be cheaper than executing own R&D projects, but not costless (Mansfield et al., 1981). As a consequence the imitator has lower overall costs and is able to outbid rivals. If spillovers ease imitation of existing products, this information most likely originates from producers within the same industry.

However, spillovers may also induce a company to perform own innovative activity. This may in particular be the case, when the input is a novel idea or a major innovation having many potential applications. This second kind of spillovers may also come from a competitor, but may also result from contacts to customers and suppliers (and research institutions as discussed below).

Obtained spillovers from customers may result in reduced risk associated with market introductions of new products and thus higher demand and sales, in particular when products may require adaptations in their use due to their complexity and novelty (see e.g. von Hippel, 1988, Herstatt and von Hippel, 1992, Tether, 2002). Spillovers from suppliers may result in process innovation for the production of existing products but also in improving existing products, e.g. in terms of design (see e.g. Suzuki, 1993, Karnath and Liker, 1994). In addition, it has been found that supplier involvement can increase product innovation in mature industries (Eisenhardt and Tabrizi, 1994).

Consequently we argue that both horizontal and vertical spillovers may affect the innovation performance of firms, where spillovers from competitors should clearly lead to higher imitation in the industry. Spillovers from customers and suppliers may affect both imitation and performance of original innovations.

Spillovers from research institutions

As already noted in the introduction, empirical research also considers the role of research institutions, in particular universities, on innovative output of firms. Much of this research focusses on regional aspects of such spillovers like the impact for companies which are residing close to universities. Other contributions look at networks or spin-offs. Furthermore the literature on regional economics and on location theory emphasizes the role of spillovers as one reason for agglomeration (see Feldmann, 1999, for a survey). This includes the location choice around universities.

Other strands of literature focusing on spillovers obtained via R&D collaborations with universitites emphasize that academic research is typically complementary to firms' own knowledge resources and thus contributes significantly to the ability of the corporate sector to create innovations (Tether and Tajar, 2008, Baba et al., 2009) including 'key innovations' as Thursby and Thursby (2006) state.

Hence we hypothesize that spillovers can be both an input for imitation as well as for innovation. Moreover, we also posit that different sources can be used for different purposes. This will be the subject of our subsequent empirical test.

3 Data and Variables

Our study is based on a sample of German firms surveyed in the year 2003, i.e., the data correspond to the years 2000-2002. The data stems from the Mannheim Innovation Panel (MIP) which is a survey conducted by the Centre for European Economic Research (ZEW), and is carried out annually since 1992 (see Janz et al., 2001, for more information on the data collection process).[3]

Our sample covers firms in the manufacturing sector. As we are interested in the effect of spillovers resulting from innovation activity, we restrict our sample to innovating firms, i.e., we end up with a sample of 1,007 firms. The definition of an innovating firm follows the OSLO manual, the international guidelines for collecting innovation data from the business sector (Eurostat and OECD, 2005).

Dependent variable

The survey allows splitting total sales into three components: a) sales with products that were newly introduced to the market between 2000 and 2002, b) sales with products that were on the market before but were new to the firm's product portfolio between 2000 and 2002, c) sales with unchanged products. We use the definition of (a) to measure original innovation, and (b) for imitation. The dependent variables are measured as percentage shares in total sales. As robustness check we also present regressions using the log of the sales volume of products (a) and (b) as dependent variables (see supplemental material).

Spillover measures

The most important explanatory variables are the spillover measures. In the MIP 2003 spell, firms were asked to indicate information spillovers that were *indispensable* for the development of an own product or process. Four different sources of such spillovers were distinguished: suppliers, customers, competitors or research institutions. Thus, we use four dummy variables indicating whether indispensable spillovers have been received. Note that the way the questions are posed implies that firms which respond in the affirmative also had the necessary absorptive capacity to make use of the information received.

Our hypothesis is that the source of spillovers is related to the firm's output. Spillovers from rivals will usually convey information on existing goods and therefore they are probably more useful for imitation rather than for innovation. Spillovers from customer, suppliers or research institutions may have very different effects, as by definition the originator of the spillovers is not active in the same industry. Therefore a positive impact on innovative output is possible. Hence we posit different effects of spillovers in dependence of the source.

Other control variables

In order to test if our spillover measures taken from the survey are superior to a more commonly used measure, we include the log of industry R&D in the regression, ln(*INDUSTRY_R&*D). This measure has been used to capture spillovers within industries by scholars who estimated production functions (see Hall et al., 2010, for an overview).

The internal knowledge stock of a company is probably an important determinant of sales realized with new products. As we only have cross-sectional data, we cannot use past R&D expenditures but linked our sample to the database of the German Patent and Trademark Office which contains both patent applications filed with the German patent office and with the European Patent Office since 1978. These data enable us to construct a stock of "successful" outcome of R&D projects for each firm from long time series. The patent stock (*PS*) of a firm is calculated by the perpetual inventory method with a constant depreciation rate as

$$PS_{it} = (1-\delta)\, PS_{i,t-1} + PA_{it} \ ,$$

where *PA* is the number of patent applications in year t and δ is the constant depreciation rate that is set to 15% (see Griliches and Mairesse, 1984, for a more detailed description). As patents are a narrower measure than an R&D knowledge stock,

[3] The MIP is the German part of the Community Innovation Survey (CIS), a harmonized survey across EU

we also include R&D spending as proxy for the non-patented knowledge stock. We use the R&D intensity, *RDINT*, measured as R&D divided by sales and also use its squared term to allow for potential decreasing marginal returns.

The share of sales volume exported (*EXPORT*) at the firm level, imports relative to domestic production (*IMPORT*) and the Herfindahl concentration index *(HERF)* at the industry level are meant to control for the competitive environment of the firm. Furthermore, we use the age of the firm (*AGE*), as younger firms might be more innovative than older ones. Size effects are considered by the number of employees (*EMP*). We use the capital intensity *(KAPINT)* defined as fixed assets divided by the number of employees as a variable indicating capital requirements. As at least a part of these capital expenditures is sunk, this variable is expected to represent barriers to entry. Ten industry dummies control differences across sectors that may not be measured by the other controls.

Timing of explanatory variables

In order to avoid endogeneity of the right-hand side variables, we use lagged values whenever possible. Basically the survey covers the innovation behavior of firms from the year 2000 to 2002. Our dependent variables refer to sales in 2002 (= t), and we can make use of one lag for the regressors. Whenever we use data from different sources (patent stock, Herfindahl index, imports) we use the information up to the year 2000, i.e. two lags, as we then make sure that the data applies to the beginning of the survey period, and risk of direct endogeneity is even less.

Employment, exports, R&D intensity and capital intensity are measured in 2001 (= t–1). The spillover measures account for the time window of 2000 to 2002. Descriptive Statistics are presented in Table 1.

Member States. For a detailed description of the CIS, see Eurostat (2004).

Table 1: Descriptive statistics (1007 observations) for the year t = 2002

Variable	Description	Mean	S. D.	Min	Max
SALES_NEW (t)	Sales from market novelties (EUR million)	13.21	128.58	0	3718.75
SALES_IMIT (t)	Sales from imitation (EUR million)	31.00	205.57	0	4224.00
%_SALES_NEW (t)	Share of sales from market novelties (%)	9.11	16.99	0	100
%_SALES_IMIT (t)	Share of sales from imitation (%)	19.12	21.21	0	100
IMPORT (t-2)	Imports (imports / domestic production)	0.38	0.33	0.07	2.19
HHI (t-2)	Herfindahl index in t-2	54.32	77.51	3.21	642.35
EMP/1000 (t-1)	Employment (in thsd.)	0.74	2.99	0.001	41.75
RDINT (t-1)	R&D spending (t-1) / Sales (t-1)	0.04	0.06	0	0.45
PS/EMP (t-2)	Patent Stock per employee (t-2)	0.02	0.05	0	0.38
EXPORT (t-1)	Exports (exports in t-1 / sales in t-1)	0.29	0.26	0	1
AGE	years elapsed since foundation	33.62	36.26	2	203
KAPINT (t-1)	Capital intensity [physical assets in million EUR (t-1) / employment (t-1)]	0.05	0.05	0.01	0.49
Ln(INDUSTRY_RD)	Log of R&D at the industry level	8.128	1.311	3.714	10.023
	Dummy variables for spillovers				
Competitors		0.20	0.40	0	1
Customers		0.51	0.50	0	1
Suppliers		0.17	0.38	0	1
Research Inst.		0.11	0.31	0	1

Note: 10 industry dummies omitted.

4 Estimation Results

As not every firm realizes sales with both market novelties and imitation, we estimate Tobit models which take account the censoring of the data. We use a log transformation of the variables to approximate the normality assumption underlying the Tobit model. As we cannot take the log of zero values, we impute the minimum observed positive value for such observations. The bias arising from this transformation should be minimal, as we just consider the smallest positive observation as censored.

The results are presented in Table 2. First, note that the results are quite robust across the two specifications of the dependent variables. We find that spillovers from universities and from customers contribute significantly to a firm's sales with market novelties, but have no effect on imitation. The marginal effects amount to 45% and 41%

in the market novelty regression. As firms on average achieve 9% of their total sales with market novelties, the estimated marginal effects imply an icrease to 13.2% if a firm indicated indispensable spillovers from academic science and to 12.8% for firms that received such spillovers from customers. Spillovers from rivals, however, have a high and significant effect on the sales with product imitation. The marginal effect amounts to 42% which corresponds to an increase in the share of new, imitated products in total sales from 19% to about 27%. Other sources do not matter for imitation which might have been expected.

These are very interesting results concerning the question which source of spillovers is useful for imitation versus innovation and they have some intuitive appeal. Information from rivals is used for imitation, as the knowledge is probably about already developed products. In contrast, knowledge inflows from research institutions and customers will rarely be about products and processes already in use. More likely is it an input which induces additional innovative activities. This is clearly one of intention of publicly funded research. In case of inducement from a customer the company in question will probably get information on market potential and this is in turn used for developing the asked for products.

In our view these results provide important information on a not much considered aspect of spillover relations. As usually an indicator for innovation is applied as the dependent variable, imitation is largely ignored. Obviously, the public opinion concerning innovation versus imitation is quite different with a more negative attitude concerning imitation. However, imitation is a fact of life and the consideration and explanation of it is has some relevance. Furthermore, as we show elsewhere (Czarnitzi and Kraft, 2012), spillovers from rivals increase profits and the present paper shows that this is not only the result of a stimulus for own innovative activity. This empirical research also contributes to the understanding of the working of markets and the success of firms.

Table 2: Tobits on log of innovation/imitation shares in total sales (1007 observation)

Variable	Market novelties		Imitation	
RDINT	10.757		10.391	***
	(6.978)		(3.869)	
RDINT^2	-11.372		-30.513	**
	(21.073)		(12.155)	
PS/EMP	8.987	***	-0.974	
	(3.408)		(1.864)	
IMPORT	1.266		-0.304	
	(1.164)		(0.635)	
HHI	-0.005	*	0.001	
	(0.003)		(0.002)	
ln(EMP)	0.263	**	0.194	***
	(0.130)		(0.061)	
EXPORT	-0.979		-0.016	
	(0.822)		(0.419)	
ln(AGE)	-0.242		-0.043	
	(0.217)		(0.105)	
KAPINT	8.516	**	-1.480	
	(4.026)		(2.112)	
ln(INDUSTRY_RD)	-0.107		-0.116	
	(0.524)		(0.276)	
Spillover measures				
COMPETITORS	-0.667		0.609	**
	(0.493)		(0.251)	
CUSTOMER	1.273	***	0.027	
	(0.413)		(0.210)	
SUPPLIERS	-0.015		-0.124	
	(0.510)		(0.261)	
RESEARCH INSTITUTIONS	1.247	**	0.194	
	(0.591)		(0.318)	
INTERCEPT	-3.602		0.403	
	(4.527)		(2.431)	
Test on joint significance of industry dummies	$\chi 2$ (10) = 26.81***		$\chi 2$ (10) =15.68	
Test on joint significance of *RDINT* and *RDINT*^{2}	$\chi 2$ (2) = 6.44**		$\chi 2$ (2) = 7.27**	
Log-Likelihood	-2129.98		-2237.90	

Note: *** (**, *) indicate a significance level of 1% (5%, 10%). Standard errors in parentheses. Tobit models would lead to inconsistent coefficient estimates if heteroscedasticity is present. Therefore we tested for heteroscedastic errors. It turned out that homoscedasticity is rejected. Consequently, heteroscedasticity was modeld as groupwise multiplicative where the variance term includes a full set of industry dummies and five size class dummies based on employment.

Among the control variables, patents are facilitating sales with market novelties. On the one hand, the patents appear to be a good proxy for a firm's inventive activity as only novel technological discoveries can be patented. On the other hand, the importance of patents in the market novelty equation, may also indicate that rivals cannot easily compete away excess returns through imitation as patents provide (at least some) protection. R&D shows an inverted U-shape in both regressions which peaks at the right tail of the R&D distribution. Thus, we basically find a positive relationship between R&D and the product innovation variables. *RDINT* and $RDINT^2$ are jointly significant at the 5% level in both equations. This also confirms the relevance of the non-patented knowledge stock.

Interstingly in contrast to other studies we cannot find an effect of industry R&D. Probably our spillover measures are better able to represent the interaction between firms than aggregated R&D expenditures. The larger firms imitate more. Finally capital intensity is positively associated with market novelties. This could be due to the existence of barriers to entry if capital requirements are high. Such firms would then be better protected against imitation by competitors.

5 Conclusion

We present the results of an empirical study concerning the impact of spillovers from different sources on innovation sales. Furthermore we distinguish between sales with actual market novelties and product imitation. Spillover from different sources do not have the same effects: While spillovers from competitors matter for imitation, customers and research institutions deliver valuable knowledge for sales with market novelties. Hence, we suggest that survey data can overcome some limitations of 'traditional' spillovers measures as these are typically not measured in an appropriate geographic area, cannot distinguish between the detailed sources, and do not allow for heterogeneous impacts across a sample of firms used for common regression analysis.

Spillovers are positive externalities and therefore positively valued by the receiving company. In contrast a firm which faces outgoing spillovers will assess the externality negatively as the advantage of it goes to competitors in the same market. These conflicting evaluations do not exist, if spillovers come from a source outside of the same industry. This is the case if the spillover stems from a research institution and customers. Such kind of information is used for innovation, not imitation and this is the reason for the uncontroversial appraisal.

Our results are also in support of the frequently observed public funding of research institutions like universities. One output of research institutes is the stimulus for successful innovation by private firms. Although the universities will receive a part of the return because they hold intellectual property rights, with some likelihood the gain for the economy is larger than that. This is the basic reason for subsidization.

References

Arrow, K.J. (1962) Economic welfare and the allocation of resources for invention, in: R.R. Nelson (ed.), *The Rate and Direction of Inventive Activity*, Princeton University Press, Princeton.

Audretsch, D.B. and M.P. Feldman (1996), R&D Spillovers and the Geography of Innovation and Production, *American Economic Review* 86, 630-640.

Audretsch, D.B., E.E. Lehmann and S. Warning (2005), University Spillovers and New Firm Location, *Research Policy* 34, 1113-122.

Baba, Y., N. Shichijo, S. Sedita (2009), How do collaborations with universities affect firm's innovative performance? The role of 'Pasteur Scientists' in the advanced materials field, *Research Policy* 38, 756-764.

Caloghirou, Y., S. Ioannides, and N.S. Vonortas, (2003), Research Joint Ventures, *Journal of Economic Surveys* 17, 541-570.

Cohen, W.M. and D.A. Levinthal (1989), Innovation and Learning: The Two Faces of R&D, *Economic Journal* 99, 569-596.

Czarnitzki, D. and K. Kraft (2012), Spillovers of Innovation Activities and Their Profitability, *Oxford Economic Papers* 64, 302-322.

D'Aspremont, C. and A. Jacquemin (1988), Cooperative and Noncooperative R&D in Duopoly with Spillovers, *American Economic Review* 78, 1133-1137.

De Bondt, R. (1996), Spillovers and Innovative Activities, *International Journal of Industrial Organization* 10, 35-54.

Eisenhardt, K. and B. Tabizi (1994), Accelerating adaptive processes: product innovation in the global computer industry, *Administrative Science Quarterly* 40, 84-110.

Eurostat (2004), *Innovation in Europe - Results for the EU, Iceland and Norway, Panorama of the European Union – Theme 9: Science and Technology*, Luxembourg: Eurostat.

Eurostat and OECD (2005), *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, 3rd Edition, Paris: OECD.

Feldman, M.P. (1999), The New Economics of Innoavtion, Spillover and Agglomeration: A Review of Empirical Studeis, *Economics of Inovation and New Technology* 8, 5-25.

Geroski, P., S. Machin, and J. Van Reenen (1993), The Profitability of Innovating Firms, *RAND Journal of Economics* 24, 198-211.

Griliches, Z., and J. Mairesse (1984), Productivity and R&D at the Firm Level, in: Z. Griliches (Ed.), *R&D, Patents and Productivity*. Chicago: University of Chicago Press: 339-374.

Grossman, G. and E. Helpman (1991), *Innovation and Growth in the Global Economy*, Cambridge, Mass., MIT Press.

Hall, B.H., J. Mairesse and P. Mohnen (2010), Measuring the returns to R&D, in: B.H. Hall and N. Rosenberg (eds.), *Handbook of the Economics of Innovation*, Elsevier.

Hanel, P. and A. St-Pierre (2002), Effects of R&D Spillovers on the Profitability of Firms, *Review of Industrial Organization* 20, 305-3222.

Herstatt, C., and E. von Hippel (1992), From experience: developing new product concepts via the lead user method: a case study in a “low-tech” field, *Journal of Product Innovation Management* 9, 213-221.

Janz, N., G. Ebling, S. Gottschalk and H. Niggemann (2001), The Mannheim Innovation Panels (MIP and MIP-S) of the Centre for European Economic Research (ZEW), *Schmollers Jahrbuch* 121, 123-129.

Jaffe, A.B. (1989), Real Effects of Academic Research, *American Economic Review* 79, 957-970.

Karnath, R. and J. Liker (1994), A second look at Japanese product development, *Harvard Business Review* 72, 154-70.

Mansfield, E. (1985), How Rapidly Does New Technology Leak Out? *Journal of Industrial Economics* 34, 217-223.

Mansfield, E. (1998), Academic research and industrial innovation: an update of empirical findings, *Research Policy* 26, 773-776.

Mansfield, E., M. Schwartz and S. Wagner (1981), Imitation costs and patents: an empirical study, *The Economic Journal* 91, 907-918.

Ponds, R., F. van Oort, and K. Frenken (2010), Innovation, Spillovers and University-Industry Collaboration: An Extended Knowledge Production Function Approach, *Journal of Economic Geography* 10, 231-255.

Romer, P.M. (1986), Increasing Returns and Long-Run Growth, *Journal of Public Economics* 94, 1002-1037.

Suzuki, K. (1993), R&D spillovers and technology transfer among and within vertical Keiretsu groups: evidence from the Japanese electrical machinery industry, *International Journal of Industrial Organization* 11, 573-591.

Tether, B. (2002), Who co-operates for innovation, and why: an empirical analysis, *Research Policy* 31, 947-967.

Tether, B. and A. Tajar (2008), Beyond industry-university links: Sourcing knowledge for innovation from consultants, private research organizations and the public science-base, *Research Policy* 37, 1079-1095.

Thursby, M. and J. Thursby (2006), Where is the New Science in Corporate R&D?, *Science* 314(8), 1547-1548.

von Hippel, E. (1988), *The Sources of Innovation*, New York: Oxford University Press.

Supplemental material

Table 3: Heteroskedastic Tobits on log sales volume of innovation/imitation (1007 observations)

Variable	Market novelties		Imitation	
RDINT	4.948		6.075	*
	(5.043)		(3.202)	
RDINT^2	-4.155		-20.817	**
	(14.586)		(9.607)	
PS/EMP	7.113	***	-1.266	
	(2.593)		(1.698)	
IMPORT	1.441		-0.365	
	(1.011)		(0.631)	
HHI	-0.004		0.001	
	(0.002)		(0.001)	
ln(EMP)	0.603	***	1.006	***
	(0.118)		(0.058)	
EXPORT	0.131		0.581	
	(0.623)		(0.379)	
ln(AGE)	-0.155		-0.074	
	(0.186)		(0.105)	
KAPINT	7.368	**	-0.432	
	(3.273)		(1.960)	
ln(INDUSTRY_RD)	-0.291		-0.351	
	(0.509)		(0.289)	
Spillover measures				
COMPETITORS	-0.289		0.695	***
	(0.388)		(0.226)	
CUSTOMERS	0.795	**	0.034	
	(0.322)		(0.185)	
SUPPLIERS	0.124		-0.130	
	(0.402)		(0.236)	
RESEARCH INSTITUTIONS	1.145	**	0.450	
	(0.461)		(0.289)	
INTERCEPT	-4.928		-3.195	
	(4.304)		(2.501)	
Test on joint significance of industry dummies	$\chi 2$ (10) = 19.21**		$\chi 2$ (10) = 16.22*	
Log-Likelihood	-2016.27		-2167.61	

Note: *** (**, *) indicate a significance level of 1% (5%, 10%). Standard errors in parentheses. The heteroskedasticity term includes a full set of industry dummies, and five size class dummies based on employment.

FACULTY OF ECONOMICS AND BUSINESS
DEPARTMENT OF MANAGERIAL ECONOMICS, STRATEGY AND INNOVATION
Naamsestraat 69 bus 3500
3000 LEUVEN, BELGIË
tel. + 32 16 32 67 00
fax + 32 16 32 67 32
info@econ.kuleuven.be
www.econ.kuleuven.be/MSI