Stocking Up: the influence of past innovativity in a region

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Abstract

Endogenous growth models are built around the concept of a knowledge stock (Romer 1990). This knowledge stock can also be interpreted as a localized stock, that operates at the regional level, connecting to the regional innovation systems literature. We use data from the second, third and fourth Community Innovation Surveys (covering 1994-1996, 1998-2000 and 2002-2004) to measure the buildup of knowledge at a very low regional level ('across streets and hallways') in the Netherlands. In doing so, we account for regional agglomeration effects. We find such local knowledge stocks have hardly any influence at all on innovativity.

Keywords

innovation, knowledge stock, endogenous growth, microdata, Community Innovation Survey

JEL codes

R10, O30, D21

1. Introduction[1]

Before the advent of the endogenous growth literature, models in regional economics ran across the road indicated by Solow (1956) and Swan (1956): labour and capital are the two producing factors. The growth rate of total production in their models is exogenous; it is supposed to capture technological factors, but is in fact a 'measure of our ignorance' (Abramovitz 1956). Paul Romer (1990) expanded the model to incorporate stocks of technology as an engine of growth. We will study these stocks at a localized level, and show their effect in the Netherlands.

2. Endogenous growth modelling

The Solow-Swan model has been influential in the economic literature over the past decades. After Romers enhancement of the base model with knowledge, the original Solow-Swan model has not gone out of fashion at all; Mankiw, Romer & Weil (1992) champion an extended version of the Solow-Swan model over endogenous growth models. In fact, a debate has been raging between adherents of both styles of modelling – a debate which is described concisely in Izushi 2008. However, instead of joining this debate, we choose to go back to a predecessor of Romer's model: Kenneth Arrow's 1962 paper on learning by doing, in which he strives to develop "an endogenous theory of the changes in knowledge" (p. 155).

In that paper, Arrow uses the stock of capital goods as a proxy for experience, which functions as a determinant of productivity. Van de Klundert & Smulders (1992) give a good overview of the theory of Arrow (and Sheshinski 1967) in a framework closely related to that of neoclassical economics[2]. They write

$$y_i = Ak_i^{\alpha} l_i^{1-\alpha} \tag{1}$$

[1] The author expresses his thanks to the Spinlab of the Vrije Universiteit Amsterdam for providing some of the necessary spatial data for this analysis, and to Habiforum for financial support. In addition, he thanks Marcel van Berlo (VU University) and Frank van Oort (Universiteit Utrecht) for their comments on earlier versions of this paper.

[2] The author thanks Henri de Groot (VU University) for this reference, and his lucid explanation thereof, as well as many other useful insights scattered *passim* throughout this paper.

at the firm level (i), with A as a technological modifier. A can then be written as the sum of all capital stocks, with an extra multiplier γ, that is the core of Arrow's reasoning (van de Klundert & Smulders 1992, footnote 3):

$$A = \left(\sum_{i \in I} k_i\right)^{\gamma} = K^{\gamma} \tag{2}$$

where K and L are the sums of all k and l's, respectively. Substituting (2) into (1) and rewriting (1) for the whole economy Y instead of for individual firms then renders

$$Y = AK^{\alpha}L^{1-\alpha} = K^{\alpha+\gamma}L^{1-\alpha} \tag{3}$$

Hence, individual firms benefit from a given technology parameter A; but the economy as a whole benefits from the accumulated technology, embedded in capital. In other words, there are increasing returns to scale at the macro level. (Those increasing returns then form a problem of their own, as they may seem to predict explosive growth – a problem treated for the case of R&D productivity in Jones 1995.)

There are many ways in which we can interpret these stocks of accumulated technology. Romer himself wrote of technological change that he interpreted it as 'improvement in the instructions for mixing together raw materials' (Romer 1990, p. S72, but cf. also Romer 1998). Yet that definition is derived from the model itself, which otherwise contains the raw inputs of capital and labour, and a human capital variable, which Solow and Swan also used. Human capital in these models is considered an embodied factor, that cannot accumulate indefinitely. Productivity then partly depends on tacit knowledge embedded in these individuals; their quality has an important influence on the results of mixing capital and labour. There are other ways to interpret the knowledge component. It might be embedded in capital goods, for example, which are far less localized than individuals. Yet for capital goods, an important part is played by knowledge about the existence of these goods, and the ability to operate, repair and improve them. In contrast to the private character of capital goods, the new factor Romer added (in Romer 1990, but cf. again Romer 1998) was meant as a nonrival technological component; knowledge that can be simultaneously used by an unlimited number of producers. In many cases empirical work has taken this to mean a stock of R&D or accumulated patents; we see this for example in the important paper by Cohen and Levinthal on absorptive capacity (1989, pp. 570-571), in the mass of literature surveyed by Wieser 2005, or in a recent article by Damijan, Kostevc & Rojec 2008, who attempt to decipher the causality issue between R&D, productivity and innovation.

3. Local innovation

Now if we go back to the micro level, to the individual firm in equation (2), the real question lies in $\sum_{i \in I} k_i$; what is the collection of relevant firms I for any individual firm i? We have assumed above that there is a 'whole economy' Y, which is traditionally a national economy, as it is in most models of endogenous growth; but the relevant scale for firms can be both larger (international) and smaller (regional). Moreover, it is not only spatial relationships that matter, but also networks of all kinds (cf. Castells 1996, Torre & Gilly 2000, and Capello & Faggian 2005).

Romers model has mainly been used to study countries; but Izushi 2008 thoroughly proves his strict model, and the alternative versions based on Lucas 1988, can be used in a regional setting just as well. We will take that approach, and look for the importance of regional knowledge stocks, focusing on a very local scale level, in line with Edward Glaeser's famous maxim "*[I]ntellectual breakthroughs must cross hallways and streets more easily than oceans and continents*." (Glaeser et al. 1992, p. 1127). Only microdata allows analyses at this scale, and its use is demonstrated for example by Wallsten 2001, who argues in favour of microdata and then proceeds to investigate whether local spillover effects exist in American banking, finding that co-location matters strongly at a radius of less than one mile.

In the current paper, we will investigate whether the stock of R&D workers can account not for *productivity*, but for the *innovativity* of firms (in constrast to Izushi 2008, pp. 955-956) at the regional scale. It is well known that other effects operate at the regional scale, determining regional innovativity. Especially since Glaeser et al. 1992, many studies have strived to discern the effects of specialization (Marshall effects, also called Marshall-Arrow-Romer effects), competition (after Porter 1990) and diversity (after Jacobs 1969). The debate on the relative importance of these factors is still very much alive – useful overviews are given in Rosenthal & Strange 2004 and Beaudry & Schiffauerova 2009, while de Groot, Poot & Smit (2009) provide a meta-analytic review of the literature.

4. Regional operationalization

One conclusion from both de Groot, Poot & Smit 2009 and the long discussion on regional constructs is that is important to have a theoretical reason to opt for a certain regional level of analysis. In our case, we believe competition effects don't take place at a regional scale in a small country such as the Netherlands; we therefore leave out competition effects. For specialization and diversity effects, we believe the *perceived* region to be of prime importance here (cf. Smit 2008). As a local example, think of a firm located just outside Amsterdam, in the Netherlands, at 15 minutes travel time. It can very well be that the firm is also at 15 minutes distance from the city of Leiden; yet a firm might feel closely connected to Amsterdam and disregard the nearness of Leiden completely (cf. Torre & Rallet 2005). Many peripheral locations around Amsterdam experience strong suburbanization forces from that city in terms of people; the entrepreneur, his employees, the firm itself might come from Amsterdam; the employees probably commute. The enterpreneur might even claim his company is located 'near Amsterdam', or 'in the urban area of Amsterdam'.[3]
Therefore we choose the so-called Corop regions as the regional level of analysis. These regions in the Netherlands are supposedly aligned with dominant cities, and shaped as their spheres of influence. Unfortunately, their borders also coincide with provincial borders, so that some idiosyncracies exist. Yet we will use these so-called Corop regions, of which there are 40, to include specialization and diversity effects in controlling for the innovativity of a firm.

The regional level we choose for our main variable of interest, however, will be a very local scale, as described above. We will use travel times to determine 'moving windows' or rings (Rosenthal & Strange 2003) of 15 minutes and 30 minutes around individual firms. The advantage of travel times is that it makes comparison between studies on different countries easier; the main advantage of moving windows is that a firm of interest is never located near the border of its region. There has been a lot of research into the importance of finding the correct regional scale and shape – cf. for example Briant, Combes & Lafourcade 2008, who find the size and especially the shape of regions matter little compared to other specification problems; but also

[3] The Boston Consulting Group, for example, has had an Amsterdam office since 1993; up to 2007, when it moved to Amsterdam Zuid, this office was located in Baarn – 30 km from Amsterdam. By Dutch standards, Baarn is not even near Amsterdam; but for BCG, this was no reason to refrain from calling their Baarn office the 'Amsterdam office'.

Burger, van Oort & van der Knaap 2007, who instead argue theoretical considerations should underly all choices a researcher makes with regard to a regional specification. We emphatically choose an intra-metropolitan scale level: we want to investigate effects that operate at such small distances that they can easily fall within the boundaries of one city or metropolitan region. At the same time, we do not exclude the countryside, where perceptions of distance and time ('pace of life') can be different, but interaction can take place all the same.

We choose our local approach on the one hand because in the polycentric, dense city structure of the Netherlands, most other analyses make no sense. An analysis at a level comparable to that of the American SMSAs would render the whole urban Randstad of the country one unit of analysis. Our level of analysis means we deliberately leave out all kinds of spillovers through networks, or even through commuting employees. On the other hand, we choose this level because we want to focus on the specific ultralocal mechanisms of knowledge transfer – face-to-face knowledge transfer, when employees meet one another at the corner bar, for example, or when startups share offices in a university-supported incubator. These mechanisms are often assumed in the literature, yet they are difficult to prove, except for anecdotical evidence (e.g. von Hippel 1986). We do not question the anecdotical evidence as such; yet we want to show whether such an ultralocal effect really matters across the economy as a whole. This also bears upon the possible benefits from cluster policy, which in the Netherlands reached its summit in the *Peaks in the Delta* report (Ministry of Economic Affairs 2004). Although we do not investigate effects at longer distances, or spillovers within non-spatial networks, or diffusion of knowledge within multiplant companies or even multinations, this is not because we believe or claim such effects do not exist. We are purely interested in local spatial interaction in this paper. Even where interference with the other effects just mentioned might exist, we still want to estimate the importance of what happens to knowledge stocks at the local scale.

5. R&D stocks

Our variable of interest is the stock of R&D in an area surrounding a firm. We will briefly discuss four issues here: the R&D variable we choose; its regional distribution; its temporal aspects; and the sectoral aspect.

The regional knowledge stock we consider is R&D efforts, proxied by the number of full-time employees working in R&D. Our data also provides us with R&D expenditures, both on in-house R&D and on externally commissioned and acquired R&D and associated capital goods (see appendix 2). We prefer the data on R&D employees. This is because externally produced knowledge that is bought by a firm will be available to other firms on the market as well, and it will have a shallower impact on the knowledge level within the firm than locally produced knowledge. Furthermore, we prefer employees over expenditure, because the knowledge is partly imbedded in the employees, and the use of expenditure might create a bias towards industries with a high ratio of capital to labour. In our dataset, we attribute all produced knowledge to the headquarters of a firm. Although this is customary, and based on the fact that most firms perform their R&D in one place only, this site of R&D production is not necessarily the headquarters. For example, Philips relocated its headquarters from Eindhoven to Amsterdam in the late 1990s; but most R&D is still performed at the Eindhoven plants, and none at the Amsterdam headquarters. Relocations of R&D facilities are not common, at least not in the Netherlands (Cornet & Rensman 2001); for the general distribution of R&D activity over the country, see appendix 3. As we have no means to adequately distribute the R&D performed by a firm to its plants, and therefore have to make do with attributing it to the HQ location.

As we have data for three years at four-year intervals (see below), we are able to do away with intricate discounting due for two reasons:

- we believe depreciation of R&D knowledge is fast, so we can disregard most knowledge that is 8 years old; this is valid for example in the IT sector, where creative destruction (Schumpeter 1942) is the rule;
- and where depreciation is not fast, and old knowledge is still current, we believe it is spatially diffused to such a degree after 8 years, that we no longer need to measure a local effect.

An important advantage of keeping the *t-8* and *t-4* periods separated is that we can still gauge how fast discounting actually goes. If both periods show up highly significant, we might conclude there could also be a leftover influence from the *t-12* period; the ideal case is where the significance levels of the *t-8* period are lower than those of the *t-4* period. Another possibility is that the *t-8* period has a negative influence on current innovativity: that would point to the law of the 'handicap of the head start' (Romein 1937).

R&D stocks are studied at a national level by Jacobs, Nahuis & Tang 2002, who employ sectoral import-output relations to symbolize the intersectoral links across which knowledge travels. We choose not to take this route, and instead focus on intrasectoral R&D versus R&D from all other sectors. Yet to account for sectoral heterogeneity, we will repeat our main analysis at various levels, defining intrasectoral R&D at four different sectoral levels:

- across 8 so-called Pavitt sectors (based on Pavitt 1984);
- across 19 macrosectors, which are listed as an appendix to this paper;
- at the 2-digit level of the Dutch SBI, which is roughly equivalent to the international NACE coding;
- at the 3-digit level of the Dutch SBI.

Ex ante, our preference is for the Pavitt classification, as this is especially geared towards classifying subsectors by their attitude towards and use of knowledge.

6. Data

We use four Dutch datasets for this analysis. Our main dataset is the fourth wave of the Community Innovation Survey (CIS). The CIS is a harmonized survey, that is conducted on a country by country basis every four years over most of Europe, and even in some countries outside Europe (notably the USA, Canada, Australia, South Africa and Norway. The fourth round covered the period 2002-2004; that is, companies were asked in 2004 to report on their behaviour over the period 2002 to 2004. We will take the final reporting year (2004) as the point of reference for CIS4 in the following, and will do so likewise with earlier rounds.

We complement this data with information from census data of all Dutch firms in 2004, the so-called Algemeen Bedrijvenregister (ABR). This we use to calculate degrees of specialization and diversity for 40 Corop regions in the Netherlands, which are similar to Chamber of Commerce areas (see above). To measure the stock of R&D, we use the second and third waves of the CIS, dating from 1996 and 2000, respectively.

Useage of the CIS dataset has some drawbacks. Although the sample taken is large – between 10.000 and 15.000 observations in each round – it still remains a sample, and although care has been taken by Statistics Netherlands to attain a reasonably balanced distribution across sectors and across firm size classes, they did not focus on the spatial distribution of firms. Yet by using only a moderate number of sectors (19 so-called macrosectors), we have observations in every region for most sectors. Also, CIS surveys ignore public sector R&D and do not mention innovations that are new to the specific market of a firm (Salazar & Holbrook 2004).[4] More critique of the CIS is given in Godin 2009. One other problem that is often encountered in firm surveys is that of distinguishing between firms and their separate plants or establishments. Luckily, in the Dutch CIS the number of multiplant firms is not very high. Data on the spread of innovations across multiplant firms is not available, unfortunately; but when we turn to R&D, a follow-up by Statistics Netherlands on CIS2 revealed that out of 3298 responses, only 399 (12%) had spread their R&D over more than one province. We will therefore ignore this issue.

To capture the regional knowledge stock, we will make use of a spatial 'moving window'. That is, using four-digit zipcode-data (2003), we construct a region around each postcode area that consists of all postcodes within 15 minutes travel time (by car), and a second ring that contains all postcodes within 30 minutes travel time. The advantage of such a methodology is that predefined regions have clear centers and edges, and that a firm at the edge of a region can be as likely to communicate with a firm just across the border as with a firm in the center of its own region. Direct physical distances overcome this problem, and can be succesfully applied nowadays as more and more microdata becomes available (cf. for example Cainelli & Lupi 2008).

We also tested a conventional k nearest neighbour approach, using k=50 for the first ring, and k=100 for the second. Although postcode areas are irregularly shaped – we used center-to-center distances, rather than border to border – the end result of these groupings resembles a circle. The size of such a circle varies with the size of the postcode areas, which in turns reflects local population density (see figures 1 and 2). In urbanized areas (see Figure 2 for Amsterdam) postcode areas are small, and so the

[4] A fundamental problem of surveys, also mentioned by Salazar and Holbrook, is of course that it is difficult to measure the quality of the answers; it is not even known who within an organization filled in the questionnaire. We assume that in most cases it will be a finance officer rather than a boasting public relations officer who fills in the questionnaire, due to the technical nature of many questions.

area covered by the first 100 postcodes (or 101, as we include the source postcode here) is small. In a more peripheral area (as in Figure 1, which shows Sappemeer, in the province of Groningen) we see that the area covered is much larger. Both maps are drawn to the same scale. That is on purpose: travel times and perceived distances will also be lower in peripheral areas, so that we are now closely aligned with a travel time model. Most of the regions had a maximum extent of between 12 and 25 km from the core. Unfortunately, regions at edges are truncated by seas or borders, and their extent away from the truncated side can become rather large. Figure 3 shows the largest distances from the core to the outermost postcode area assigned to the region; there are extreme regions where the furthest postcode area is 47 km away from the core area. Therefore we decided not to go ahead with a nearest neighbours specification.

Figure 1: 100 postcode areas nearest to 9611 (Sappemeer). Darker colours indicate a lower rank, i.e. closer proximity to the core of the region. Outside the 100 postcode areas, municipality borders and names are indicated.

Figure 2: 100 postcode areas nearest to 1011 (central Amsterdam). Note that the map has the same scale as Figure 1.

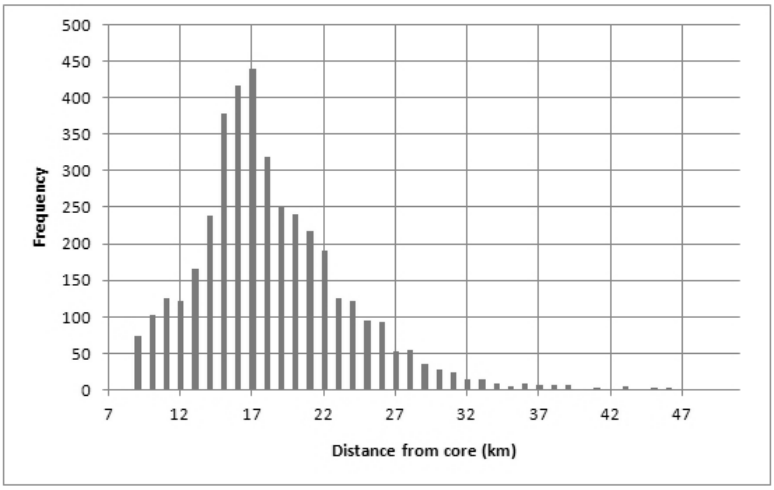

Figure 3: Histogram of distances from the 100th nearest postcode to the core.

7. Analysis

We will test the main hypothesis whether a firm profits from previous innovativity in its region. For our analysis, we will employ to a probit model. A simple probit model estimates a latent variable Y* (∈ ℝ); if Y*>0, the model predicts a success (Y=1), otherwise it predicts Y=0. Our full model looks like this:

$$Y^* = \alpha + \beta PREV_{r,s,t} + \gamma_1 OAD + \gamma_2 VARY + \gamma_3 SPEC + \gamma_4 SIZE + sectoral\ dummies + \epsilon \quad (4)$$

where *PREV* represents the total regional R&D effort around a firm. We can measure *PREV* at different sectoral levels, as discussed above. Our basic specification is at the 2-digit SBI level. Our *PREV* variable has the following three dimensions, leading to $2^3=8$ distinct variables:

- *r*, two geographical areas: an inner ring, formed by the nearest 50 postcodes, and an outer ring, consisting of the next nearest 50 postcodes, as shown in Figures 2 and 3 above;
- *s*, intrasectoral and intersectoral effects: we include both the number of innovations within the sector of a firm, and those in all other sectors.
- *t*, two time periods: the previous (CIS3, for 1998-2000) and the one before that (CIS2, for 1994-1996);

The other variables, which all refer to the year 2004, are:

- OAD: a measure of urbanity, calculated by Statistics Netherlands ('omgevingsadressendichtheid') as the density of unique addresses in a postcode area, and measured in five classes, ranging from very urban (1) to rural (5). Figure 4 shows this measure for the densely populated area between Amsterdam and Rotterdam.
- VARY: a measure of diversity (Jacobs effects): a Hirschman-Herfindahl index at the 2-digit sectoral level, measured by COROP region.
- SPEC: a measure of specialization (MAR effects): a location quotient at the 2-digit sectoral level.
- SIZE: two variables measuring the size of a firm: its number of employees and its total turnover.

Finally, we add a dummy for firms located in the three Randstad provinces. Although urban effects are captured already by the urbanity variable, the Randstad has more locational advantages: proximity to the main airport (Schiphol), to the national government (The Hague), and excellent transport links to all of the country.

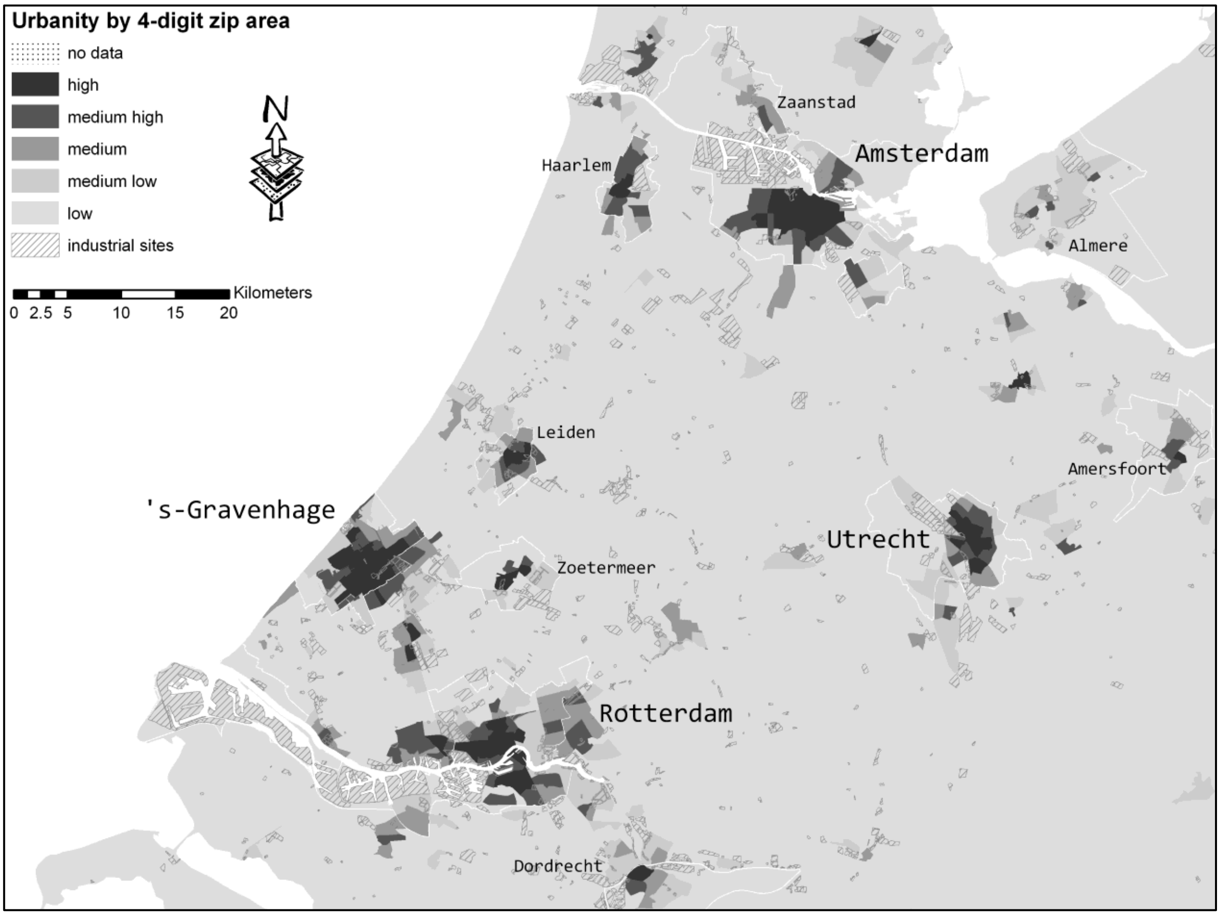

Figure 4: Urbanity in the Randstad.

Note that we do not take into account the indirect effect of the innovation stock of period 2; of course the innovativity in that period also had an influence on the firms of period 3.

8. Results

The results of our analysis are displayed in Tables 1 and 2. Table 1 gives the basic result; table 2 gives more detailed results for five major Pavitt sectors; and table 3 ventures a bit deeper into some subcategories of the data to explore whether any regional effect can be found there.

Table 1: Main results. As customary, * indicates significance at 10%, ** at 5%, *** at the 1% level. (Note: kfte = 1000s of full time employees.)

Dependant: firm innovated in CIS4.	(1: Pavitt)		(2: macrosectors)		(3: SBI 2-digit)		(4: SBI 3-digit)	
	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.
Firm level variables								
R&D fte of the firm (in logs)	***0.324	(0.02)	***0.324	(0.02)	***0.323	(0.02)	***0.322	(0.02)
turnover (in logs of €, 2004)	***0.098	(0.01)	***0.096	(0.01)	***0.097	(0.01)	***0.096	(0.01)
employees (in logs of 1000s, 2004)	***0.101	(0.02)	***0.103	(0.02)	***0.103	(0.02)	***0.102	(0.02)
R&D variables (at sectoral level indicated above)								
R&D kfte in CIS2, inner ring, same sector	0.272	(0.22)	0.212	(0.26)	-0.513	(0.72)	**1.211	(0.56)
R&D kfte in CIS2, outer ring, same sector	-0.034	(0.09)	0.157	(0.12)	0.067	(0.34)	-0.591	(0.53)
R&D kfte in CIS3, inner ring, same sector	-0.146	(0.17)	-0.077	(0.21)	*0.771	(0.46)	-0.430	(0.64)
R&D kfte in CIS3, outer ring, same sector	0.078	(0.07)	-0.001	(0.09)	0.323	(0.30)	**0.914	(0.38)
R&D kfte in CIS2, inner ring, other sectors	0.024	(0.06)	0.027	(0.06)	-0.001	(0.06)	0.011	(0.06)
R&D kfte in CIS2, outer ring, other sectors	*0.068	(0.04)	0.056	(0.03)	0.048	(0.03)	0.050	(0.03)
R&D kfte in CIS3, inner ring, other sectors	0.005	(0.05)	0.002	(0.05)	0.019	(0.05)	0.016	(0.05)
R&D kfte in CIS3, outer ring, other sectors	-0.048	(0.03)	-0.039	(0.03)	-0.028	(0.03)	-0.030	(0.03)
Regional variables								
Diversity (HHI, 2004)	0.209	(1.10)	0.280	(1.09)	0.337	(1.09)	0.418	(1.09)
Specialization (LQ, by 2-digit sector, 2004)	**0.080	(0.03)	**0.070	(0.03)	**0.079	(0.03)	***0.086	(0.03)
Randstad dummy	***-0.123	(0.04)	***-0.117	(0.04)	***-0.121	(0.04)	***-0.126	(0.04)
urbanization ('o.a.d.')								
high	omitted		omitted		omitted		omitted	
medium-high	0.024	(0.06)	0.023	(0.06)	0.019	(0.06)	0.024	(0.06)
medium	0.079	(0.06)	0.078	(0.06)	0.075	(0.06)	0.082	(0.06)
medium low	***0.158	(0.06)	***0.157	(0.06)	**0.150	(0.06)	***0.157	(0.06)
low	0.077	(0.06)	0.079	(0.06)	0.076	(0.06)	0.080	(0.06)
constant	***-2.082	(0.14)	***-2.070	(0.14)	***-2.082	(0.14)	***-2.095	(0.14)
observations	7675		7675		7675		7675	
mcfadden's pseudo-r^2	0.095		0.096		0.095		0.096	

Table 2: Results for selected Pavitt sectors, with R&D calculated at the 2-digit SBI level.

Dependant: firm innovated in CIS4.	(5: Science Based)		(6: Scale Intensive)		(7: Information Intensive)		(8: KIBS)		(9: Traditional Services)	
	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.
Firm level variables										
R&D fte of the firm (in logs)	***0.477	(0.09)	***0.250	(0.05)	***0.631	(0.21)	***0.256	(0.04)	***0.225	(0.05)
turnover (in logs of €, 2004)	**0.124	(0.06)	***0.120	(0.03)	0.078	(0.07)	***0.115	(0.03)	***0.066	(0.03)
employees (in logs, 2004)	-0.022	(0.11)	***0.210	(0.05)	**0.310	(0.12)	0.013	(0.03)	***0.110	(0.04)
R&D variables (at 2-digit SBI level)										
R&D kfte in CIS2, inner ring, same sector	-30.301	(19.90)	-4.796	(3.18)	-15.730	(14.73)	-0.283	(2.74)	0.239	(0.94)
R&D kfte in CIS2, outer ring, same sector	9.939	(7.80)	-0.940	(1.54)	4.623	(4.84)	1.622	(1.80)	*0.776	(0.43)
R&D kfte in CIS3, inner ring, same sector	24.883	(22.08)	***8.370	(2.83)	-1.950	(13.20)	*3.088	(1.82)	1.355	(1.39)
R&D kfte in CIS3, outer ring, same sector	12.806	(15.82)	**2.593	(1.04)	-3.464	(4.50)	*-2.064	(1.08)	0.966	(0.69)
R&D kfte in CIS2, inner ring, other sectors	0.357	(0.27)	**-0.349	(0.17)	0.540	(0.42)	-0.128	(0.13)	0.198	(0.14)
R&D kfte in CIS2, outer ring, other sectors	0.116	(0.19)	0.081	(0.07)	0.033	(0.21)	***-9460.000	(0.07)	0.123	(0.08)
R&D kfte in CIS3, inner ring, other sectors	-0.310	(0.23)	*0.260	(0.14)	-0.366	(0.36)	0.143	(0.11)	-0.145	(0.12)
R&D kfte in CIS3, outer ring, other sectors	-0.158	(0.16)	-0.019	(0.06)	0.011	(0.18)	-0.047	(0.06)	-0.090	(0.07)
Regional variables										
Diversity (HHI, 2004)	-0.279	(7.00)	-1.254	(3.03)	6.534	(5.50)	-1.315	(2.05)	-0.892	(3.19)
Specialization (LQ, by 2-digit sector, 2004)	0.011	(0.11)	-0.112	(0.22)	-0.325	(0.38)	*0.300	(0.17)	-0.308	(0.39)
Randstad dummy	-0.207	(0.21)	***-0.344	(0.08)	0.037	(0.31)	-0.064	(0.11)	*-0.129	(0.07)
urbanization ('o.a.d.')										
high	omitted		omitted		omitted		omitted		omitted	
medium-high	-0.049	(0.39)	-0.049	(0.151)	0.096	(0.284)	-0.064	(0.11)	0.164	(0.11)
medium	0.490	(0.37)	-0.041	(0.148)	-0.123	(0.324)	-0.026	(0.11)	0.105	(0.12)
medium low	0.181	(0.36)	-0.115	(0.145)	0.578	(0.397)	0.133	(0.12)	**0.241	(0.12)
low	0.017	(0.36)	0.056	(0.142)	0.522	(0.430)	-0.040	(0.13)	0.063	(0.12)
constant	*-1.438	(0.84)	***-2.389	(0.471)	***-2.876	(0.734)	***-1.704	(0.30)	***-1.693	(0.63)
observations	327		2116		209		1463		2295	
mcfadden's pseudo-r^2	0.2057		0.1410		0.2983		0.0620		0.0616	

Table 3: Results by size class of the firm. R&D calculated at the 2-digit SBI level.

Dependant: firm innovated in CIS4.	(10: 10-49)		(11: 50-249)		(12: 250-499)		(13: 500-999)		(14: 1000+)	
	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.
Firm level variables										
R&D fte of the firm (in logs)	***0.141	(0.04)	***0.379	(0.03)	***0.483	(0.07)	***0.555	(0.10)	***0.589	(0.14)
turnover (in logs of €, 2004)	***0.066	(0.02)	***0.125	(0.02)	***0.180	(0.05)	**0.172	(0.08)	*0.187	(0.11)
employees (in logs, 2004)	***0.203	(0.04)	***0.128	(0.04)	-0.001	(0.11)	0.074	(0.14)	-0.004	(0.16)
R&D variables (at 2-digit SBI level)										
R&D kfte in CIS2, inner ring, same sector	-0.640	(1.28)	-1.006	(1.11)	-1.520	(3.34)	3.694	(3.85)	5.580	(3.42)
R&D kfte in CIS2, outer ring, same sector	0.063	(0.54)	0.253	(0.51)	1.234	(1.88)	-2.184	(2.52)	-3.831	(3.75)
R&D kfte in CIS3, inner ring, same sector	**1.678	(0.85)	-0.210	(0.83)	0.865	(2.94)	-0.420	(0.66)	-3.245	(2.94)
R&D kfte in CIS3, outer ring, same sector	0.367	(0.43)	0.272	(0.48)	-0.065	(1.00)	0.500	(2.50)	-0.109	(3.17)
R&D kfte in CIS2, inner ring, other sectors	0.074	(0.08)	-0.075	(0.11)	0.069	(0.30)	-0.283	(0.46)	0.597	(0.82)
R&D kfte in CIS2, outer ring, other sectors	*0.074	(0.04)	0.010	(0.06)	-0.131	(0.16)	-0.314	(0.26)	0.350	(0.31)
R&D kfte in CIS3, inner ring, other sectors	-0.019	(0.07)	0.071	(0.09)	-0.089	(0.25)	0.173	(0.30)	-0.609	(0.72)
R&D kfte in CIS3, outer ring, other sectors	-0.038	(0.04)	-0.042	(0.05)	0.217	(0.14)	0.353	(0.23)	-0.225	(0.26)
Regional variables										
Diversity (HHI, 2004)	0.336	(1.56)	0.903	(1.78)	0.682	(4.44)	4.327	(6.98)	-5.902	(8.65)
Specialization (LQ, by 2-digit sector, 2004)	*0.082	(0.05)	0.073	(0.05)	0.062	(0.19)	0.360	(0.40)	0.223	(0.38)
Randstad dummy	**-0.112	(0.05)	*-0.119	(0.06)	-0.058	(0.17)	*-0.429	(0.26)	0.010	(0.37)
urbanization ('o.a.d.')										
high	omitted		omitted		omitted		omitted		omitted	
medium-high	-0.066	(0.08)	0.129	(0.100)	-0.087	(0.238)	0.164	(0.34)	0.023	(0.45)
medium	0.069	(0.08)	0.145	(0.101)	-0.165	(0.246)	-0.228	(0.35)	0.365	(0.47)
medium low	0.119	(0.08)	**0.258	(0.100)	-0.058	(0.280)	-0.120	(0.41)	0.186	(0.49)
low	0.029	(0.08)	*0.188	(0.103)	-0.065	(0.239)	0.060	(0.35)	0.222	(0.49)
constant	***-2.116	(0.21)	***-2.573	(0.280)	***-2.428	(0.788)	**-3.270	(1.38)	-2.526	(1.76)
observations	4270		2717		372		194		122	
mcfadden's pseudo-r^2	0.0337		0.0925		0.1810		0.2659		0.3199	

Our main result appears immediately: there is hardly any significant effect for any of the eight knowledge stock variables in the pooled regression in table 1. Only at the 3-digit sectoral level (regression 4) two variables are significant at the 5% level, both of which are within-sector effects. They are a positive effect for the inner ring at *t-8*, and a positive effect for the outer ring at *t-4*, which is puzzling, as their more immediate counterpart – the inner ring effect for *t-4*, which is nearer in space than the one and nearer in time than the other – is not only insignificant but also negative. In the regressions by firm size the expected effect appears, however, for the smallest size category (10-49 employees, equation 10), where the inner ring for *t-4* has a positive and significant coefficient, with as expected a lower coefficient for the outer ring for that same period. The only other place where this distance decay neatly occurs is for the scale intensive sector (regression 6), which in addition also has a signficant cross-sectoral effect for the *t-4* inner ring. The fact that among all five Pavitt sectors we consider[5] only this sector clearly and 'correctly' shows the knowledge stock effect we set out to test for might imply the time frame we chose is too long for most knowledge spillovers. We might argue that large parts of the scale intensive industry are also capital intensive, and that their innovations consist of replacing large-scale capital goods. In that case, they would be the slowest sector to enjoy the effects of regional knowledge stocks; and if they are the slowest, that can be a reason why only in this sector, and then only for the *t-4* period, a signficant effect of knowledge stocks appears.

Among the cross-sectoral coefficients, reported in all regressions as the second batch of four variables, we find a few results significant at the 10% level, plus one coefficient which is significant at the 5% level (regression 6, discussed above) and one humongous coefficient which is significant at the 1% level (regression 8); notwithstanding its high significance level, we will ignore this coefficient as an outlier.

We are then left with barely any results for our knowledge stock variables, apart from the good results in regression 6, and the results from regression 4 which did not follow the usual rules of spatial and temporal decay. Now of course the fact that coefficients are not significantly different from zero does not imply that they are unimportant (McCloskey 1985), yet we take the lack of consistent significant results

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[5] See the first appendix for a brief overview of the sectoral composition of the Pavitt sectors. Note that the 'scale intensive' sector also includes the Transport and Communication subsector, which in turn contains not only Land, Water and Air transport and a category called "Transport and Travel Auxiliary", but also "Post and Telecommunication".

to indicate that *there is no effect of a local knowledge stock* over a four to eight years period.

Compared to this rather shocking main result, interpretation of the rest of our results is less exciting. Yet there are some interesting points to discuss. First of all, none of our fourteen regressions show no significant effect of diversity – contrary to what Glaeser et al. 1992 and many others found (de Groot, Poot & Smit 2009). There does appear to be a positive influence of specialization in the pooled regressions (1-4), which all but disappears when we consider separate Pavitt sectors or size classes.

Both firm size, measured in turnover or in employees, and own R&D by the firm in question appear to be a significant predictor of innovativity. This can indicate either scale effects or an indirect effect of firm age, for which we unfortunately have no data. For firms larger than 250 employees (regressions 12-14), it is turnover rather than size in employees that matters; for some of the Pavitt sectors, it is either turnover or employees that matters (regressions 5, 7 and 8).

As an interesting aside, we note that the information intensive sector (regression 7), which consists of banking and insurance, shows an unusually high R^2. Judging from the significance levels of the independent variables in that regression, these results are to a large degree driven by the R&D effort of the individual firms. This may therefore be an outcome of the CIS as a survey – as the recognition of innovation in services is relatively new, those firms that perceive themselves as innovators are also able to perceive part of their staff as working on R&D.

Finally, we have the randstad dummy and the urbanization variable, which was operationalized as five classes to allow for non-linearity. The randstad dummy is significant in the pooled regressions, but negative; in the other regressions, the effect is sometimes significant, and in three cases positive, but never at the same time. Apparently, being located in the randstad hampers innovativity when we control for other agglomeration variables and for R&D. The urbanization variable shows significantly positive results for the 'medium low' category in the pooled regression; but regressions 9 and 11 are the only other places where this effect reappears, indicating that it might be driven by medium-sized traditional services in the first place. This hypothesis fits in well with our figure 3, which shows this result can not be linked to industrial sites, which are mostly located in the last, category 'low density'.

9. Conclusions

There appears to be no general knowledge stock effect in the Netherlands at a very localized level, except in the scale intensive industries (food, metals, construction). That does not imply there are no knowledge spillovers; it is well possible that the scope of such spillovers is much larger than we investigated here, or that their speed is much faster than the 4-8 years we accounted for, so that spillovers cannot be measured at all with a four-yearly survey. It is also possible that use of regional knowledge stocks only occurs at a very detailed sectoral level, such as a survey cannot possibly uncover, but qualitative research can. In that case, however, we should question whether there is a case to be made for the strong public focus on clustering and the associated intercity competition within the Netherlands.

Appendix 1: sector classification

Pavitt sector	macrosector	SBI 2-digit sector
Primary	Mining and Quarrying	Mining of Coal
		Extraction
		Other Mining
Science Based	Chemicals	Coke and Petroleum
		Chemicals
		Rubber and Plastic
		Other Non-Metal Minerals
Specialised Suppliers	Machinery and Equipment	Machinery and Equipment
		Office Machinery and Computers
		Electrical Machinery
		Communication Equipment
		Optical Instruments
		Motor Vehicles
		Other Transport Equipment
Scale Intensive	Food, Beverage and Tobacco	Food and Beverage
		Tobacco
	Metals	Basic Metals
		Fabricated Metals
	Electricity, Gas and Water	Electricity, Gas and Water
		Water Purification and Distribution
	Construction	Construction
	Transport and Communication	Land Transport
		Water Transport
		Air Transport
		Transport and Travel Auxiliary
		Post and Telecommunication
Supplier Dominated	Textile, Clothes and Leather	Textiles
		Clothes
		Leather
	Wood, Paper and Pulp	Wood
		Pulp and Paper
		Publishing and Printing
	Manufacturing n.e.c.	Furniture n.e.c.
		Recycling
Information Intensive	Financial Intermediation	Financial Intermediation
		Insurance
		Other Financial Services
KIBS	Computer and Related	Computer and Related Activities
	Research and Development	Research and Development
	Business Services	Other Business Services
Traditional services	Wholesale Trade and Repair	Trade and Repair of Motorvehicles
		Wholesale Trade
	Retail Trade	Retail Trade
	Hotels and Restaurants	Hotels and Restaurants
	Real Estate and Renting of Machinery	Real Estate
		Renting of Machinery and Equipment

Appendix 2: Questionnaires

As a short introduction to the CIS questionnaires, we here give some of the relevant questions from the CIS4. Our basis is the harmonized English-language survey questionnaire. A complete version of the questionnaire is currently available from the OECD website at http://www.oecd.org/dataoecd/52/35/40140021.pdf.

A product innovation is the market introduction of a *new* good or service or a *significantly* improved good or service with respect to its capabilities, such as improved software, user friendliness, components or sub-systems. The innovation (new or improved) must be new to your enterprise, but it does not need to be new to your sector or market. It does not matter if the innovation was originally developed by your enterprise or by other enterprises.

2.1 During the three years 2002 to 2004, did your enterprise introduce (yes/no):

- New or significantly improved goods. (Exclude the simple resale of new goods purchased from other enterprises and changes of a solely aesthetic nature.)
- New or significantly improved services.

2.3 Were any of your goods and service innovations during the three years 2002 to 2004 (yes/no):

- New to your market? (Your enterprise introduced a new or significantly improved good or service onto your market before your competitors. It may have already been available in other markets.)
- Only new to your firm? (Your enterprise introduced a new or significantly improved good or service that was already available from your competitors in your market.)

x.x[6] Using the definitions above, please give the percentage of your total turnover in 2004 (in %) from:

- Goods and service innovations introduced during 2002 to 2004 that were *new to your market*;
- Goods and service innovations introduced during 2002 to 2004 that were *only new to your firm*;
- Goods and services that were *unchanged or only marginally modified* during 2002 to 2004 (include the resale of new goods or services purchased from other enterprises).

A process innovation is the implementation of a *new* or *significantly* improved production process, distribution method, or support activity for your goods or services. The innovation (new or improved) must be new to your enterprise, but it does not need to be new to your sector or market. It does not matter if the innovation was originally developed by your enterprise or by other enterprises. Exclude purely organisational innovations.

3.1 During the three years 2002 to 2004, did your enterprise introduce (yes/no):

- New or significantly improved methods of manufacturing or producing goods or services.
- New or significantly improved logistics, delivery or distribution methods for your inputs, goods or services.
- New or significantly improved supporting activities for your processes, such as maintenance systems or operations for purchasing, accounting, or computing.

4.1 Did your enterprise have any innovation activities to develop product or process innovations that were abandoned during 2002 to 2004 or still ongoing by the end of 2004 (yes/no)?

If your enterprise had no product or process innovations or innovation activity during 2002 to 2004 (no to all options in questions 2.1, 3.1, and 4.1), go to question 8.2 Otherwise, go to question 5.1.

5.1 During the three years 2002 to 2004, did your enterprise engage in the following innovation activities (yes/no):

- Intramural (in-house) R&D: creative work undertaken within your enterprise to increase the stock of knowledge and its use to devise new and improved products and processes (including software development)
    - if yes, did your firm perform R&D during 2002 to 2004 continuously or occasionally?

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[6] No question number is given in the questionnaire for this.

— Extramural R&D: same activities as above, but performed by other companies (including other enterprises within your group) or by public or private research organisations and purchased by your enterprise.
— Acquisition of machinery, equipment and software: acquisition of advanced machinery, equipment and computer hardware or software to produce new or significantly improved products and processes.
— Acquisition of other external knowledge: purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge from other enterprises or organisations.
— Training: internal or external training for your personnel specifically for the development and/or introduction of new or significantly improved products and processes
— Market introductions of innovations: activities for the market introduction of your new or significantly improved goods and services, including market research and launch advertising
— Other preparations: procedures and technical preparations to implement new or significantly improved products and processes that are not covered elsewhere.

5.2 Please estimate the expenditure for each of the following four innovation activities in 2004 only. (Include personnel and related costs.)
— Intramural (in-house) R&D: include capital expenditures on buildings and equipment specifically for R&D.
— Acquisition of R&D (extramural R&D).
— Acquisition of machinery, equipment and software: exclude expenditures on equipment for R&D.
— Acquisitions of other external knowledge.
— Total of these four innovation expenditure categories.

Appendix 3: Regional distribution of R&D in the Netherlands

Source: CBS Statline.

	R&D staff	total employment	R&D in % of employment	R&D staff	total employment	R&D in % of employment	change (%-point)
		2002			2007		2002-2007
Groningen	777	229.200	0,34%	418	247.400	0,17%	-0,17%
Friesland	923	235.800	0,39%	1.013	252.500	0,40%	0,01%
Drenthe	562	174.200	0,32%	923	192.000	0,48%	0,16%
Overijssel	3.630	455.100	0,80%	3.372	514.300	0,66%	-0,14%
Flevoland	367	111.500	0,33%	970	140.300	0,69%	0,36%
Gelderland	4.858	800.100	0,61%	4.075	899.000	0,45%	-0,15%
Utrecht	2.613	602.300	0,43%	3.488	659.600	0,53%	0,09%
Noord-Holland	7.468	1.266.300	0,59%	6.436	1.402.200	0,46%	-0,13%
Zuid-Holland	7.143	1.522.500	0,47%	7.115	1.662.900	0,43%	-0,04%
Zeeland	757	139.300	0,54%	774	149.600	0,52%	-0,03%
Noord-Brabant	14.235	1.058.300	1,35%	17.345	1.208.300	1,44%	0,09%
Limburg	3.700	464.000	0,80%	3.317	500.500	0,66%	-0,13%
total	47.033	7.058.600	0,67%	49.246	7.828.600	0,63%	-0,04%

R&D staff is in years, only counting companies >10 employees;
total employment is measured in jobs.

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