Regional Labour Productivity in The Netherlands
Diversification and Agglomeration Economies

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and

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Abstract

This paper studies the extent to which diversification and agglomeration effects account for regional differences in labour productivity and labour productivity growth. Using a large set of regional data for The Netherlands between 1990-2001 we found that roughly 60% of the explained variation in regional productivity differences and 55% of the regional growth differences can be attributed to indicators of diversification and agglomeration effects A sensitivity analysis shows these effects are fairly robust.

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1. Introduction

Labour productivity has become one of the main focal points of economic research and policy in recent years. The level of labour productivity in The Netherlands is high compared to other countries. McGuckin and van Ark (2004) show that in 2003 only Luxemburg, Norway, Belgium and Ireland precede The Netherlands in terms of GDP per hour worked. However, growth rates of labour productivity in The Netherlands, and in fact all over Europe, are far below growth rates of the USA. Country comparisons of productivity growth rates have been conducted at a wide scale now. Typical suspects of variables that help explain differences in productivity growth between countries are differences in use of ICT equipment, innovations, scale of business operations, the level and change in product market and labour marker regulations. See Schreyer (2002), Oliner and Sichel (2003), van Ark et al. (2002a, 2002b).

However, moving the centre of attention to regions within a country might help us to get a grip on additional factors that help explain labour productivity and labour productivity growth in a country. Usual suspects that help explain regional differences in labour productivity growth are agglomeration effects, regional specialisation or regional diversification. See Ciccone and Hall (1996) and Ciccone (2002). When such an analysis would be repeated for other countries this might provide additional support of alternative explanations for the gap in productivity growth between countries as well.

This paper puts agglomeration effects and regional diversification to the test as explanatory variables for regional labour productivity and regional labour productivity growth in The Netherlands, together with a set of the more usual explanatory variables. As first step a shift-share analysis is conducted in Oosterhaven and Broersma (2004), which yields the input of some of the explanatory variables for this study. Both the shaft-share analysis and the regression analysis of this paper are based a rich data set consisting of 21 sectors for each of 40 regions during 12 years (1990-2001).

We find evidence of agglomeration advantages for the level of labour productivity, i.e. a high density of economic activities – measured as the number of jobs per km^2 – has a positive effect on productivity. The size of this effect compares very well to values found for other countries: when job density doubles productivity rises with roughly 5%. See Ciccone and Hall (1996) and Ciccone (2003). However, the effect of job density on the growth rate of labour productivity is negative, i.e. agglomeration disadvantages. Hence accumulation of economic activities has a positive effect on the level of productivity, but at the same time an impeding effect on growth of productivity. The job density in surrounding regions has an opposing effect on productivity (growth). High densities in surrounding regions dim the positive effect of job density on the level of productivity; high densities in neighbouring regions dim the negative effect of job density on productivity growth. We also find that the more a regional economy is diversified (towards some 'optimally' diversified economy) the higher labour productivity. There is no effect of diversification on productivity growth.

This paper is organised as follows. Section 2 describes theoretical starting points when it comes to analysing the effect of agglomeration effects on productivity. Section 3 is about the data that were used and the consequences for the model specifications we are going to estimate and provide information on econometric issues. Section 4 presents the estimation results for both the level and growth of labour productivity and provides an interpretation. Finally section 5 concludes.

2. Theoretical explanation of regional productivity differences

2.1. Agglomeration economies

Starting-point for regional and other differences in labour productivity is the micro economic theory of producer behaviour. Each type of product (or each industry) has its own production function and factor prices that differ by region or otherwise. In such a situation a producer will produce a good or service (in a certain region) with a profit maximising combination of production factors. The ratio of production over the optimal amount of labour input yields labour productivity in terms of production per unit of labour. Obviously when factor prices differ per region, it is likely that the same producer of the same product (or in the same industry) will realise a different optimal level of production per unit of labour, i.e. different levels of labour productivity, in a different region. In regions with relatively low wages, producers will choose a more labour-intensive way of production and hence for a lower (optimal) labour productivity level.

Hence, theoretically regional productivity differences are a consequence of regional price differences. Besides this rational behaviour location there may also be other more personal motives that determine the place of business. The functioning of markets will however result in the fact that producers who have taken non-optimal location and factor decisions will grow less compared to those who did take the right decisions. So the actual pattern of regional labour productivity will be much more determined by regional price differences than by any subjective individual decision-making.

For a standard profit maximising firm, in a Cobb-Douglas production function setting in a certain region, labour productivity is directly related to the real regional wage rate, i.e. to regional wages and regional prices. However most countries have no information regarding regional price levels. Nevertheless, even without information on regional differing prices, the production function remains of direct importance for explaining differences in labour productivity. At an aggregate level assume a Cobb-Douglas production function with production factors labour (L), capital (K) and intermediate inputs from various industries i (Z_i)

$$Y = A\, K^{\kappa} L^{\lambda} \Pi_i (Z_i^{\xi i}), \tag{1}$$

where Y is nominal output, Π_i denotes multiplication over all i industries, A is the level of (disembodied) technological progress and κ, λ and ξ_i are positive parameters. When there are constant returns to scale ($\kappa+\lambda+\Sigma_i\xi_i=1$), we can rewrite (1) into

$$Y/L = A\, (K/L)^{\kappa} \Pi_i (Z_i/L)^{\xi i} \tag{2}$$

From (2) we see that labour productivity (Y/L) is a function of the capital-labour ratio (K/L) and possibly of the ratio between any of the intermediate inputs and labour (Z_i/L).

At the aggregate level, equation (1) still assumes homogeneous factors of production K, L and Z_i. In the new spatial economics this assumption is relaxed and inputs Z_i are considered to be heterogeneous. A firm that can choose from a larger variety of input Z_i will realise a higher output Y[1], or

$$Z_i = (\Sigma_w Z_{iw}^{\varpi i})^{1/\varpi i}, \tag{3a}$$

[1] This implies the market form is no longer a competitive market, but rather a market of monopolistic competition. We use the specification of Dixit en Stiglitz (1977), as introduced in this new spatial economics by Krugman (1991) and Venables (1996).

where ϖ_i is the substitution parameter of varieties w in industry i. For example if the industry i in (3a) refers to advertising than (3a) shows that use of more differently specialised advertising agencies (Z_{iw}) will yield higher intermediate inputs Z_i and hence higher output Y than when one single advertising agency was used (Z_i).

We realise that this sub-production function (3a) will not only apply to intermediate inputs Z_i, but also to labour inputs L[2]

$$L = (\Sigma_v L_v^{\upsilon})^{1/\upsilon}, \tag{3b}$$

where υ is the substitution parameter for different types of labour v. Equation (3b) shows that using a wide variety of different (heterogeneous) types of labour will also result in a higher output Y than when only one type of (homogeneous) labour was used. Equation (3) is about the effect of a better matching between the demand and supply of labour of different qualities.

The economies of scale in (3a) and (3b) of having a larger variety of suppliers and labour at one's disposal in a region, are a consequence of market transactions and are not technology-driven. In fact, (3a) and (3b) give rise to two types of agglomeration economies known from international literature:

1. localisation economies: the abundance of specific labour and specific suppliers for a specific industry;
2. urbanisation economies: the abundance of non-industry specific labour and suppliers.

Next to these non-technological advantages we also have technological external effects. These effects do not come about by means of market transactions, but instead enter the production function (1) directly through a higher value of A. This is usually associated to the transfer of knowledge between firms, without any supplier relation or labour relation. Modern-day growth literature distinguishes between urbanisation economies and two types of localisation economies:[3]

1. Jacobs urbanisation economies: knowledge spill-overs between firms from different industries, where diversity enhances spill-overs;

2a. Marshall-Arrow-Romer localisation economies: knowledge spill-overs within an industry where local monopolies enhance spill-overs;

2b. Porter localisation economies: knowledge spill-overs within an industry where local competition enhances spill-overs.

Hence, different concepts can be distinguished from the literature, but in fact there is a continuum of agglomeration economies.

2.2. Model specification

In this paper we are going to conduct a regression analysis in order to explain regional differences in labour productivity (growth). The specification that is going to be estimated can directly be derived from (1). When value added is chosen to represent output, then there is no need to take intermediate supply into consideration and (1) collapses into

$$Y = A\, K^{\kappa} L^{\lambda}. \tag{4}$$

Taking account of a log-linear specification, constant returns to scale and taking regional labour productivity relative to national, (4) can be rewritten as

[2] This generalisation in fact will also apply to the capital stock, but for this study we assume it is unlikely that there are many different varieties of the same type of capital good per region. Therefore a similar distinction for K is not taken into account here.

[3] See Glaeser (e.a. 1992), Brakman (e.a. 2000) and van Oort (2004).

$$\left[\log(Y_r / L_r) - \log(Y_n / L_n)\right] = \gamma_0 + \kappa_r \log(K_r / L_r) - \kappa_n \log(K_n / L_n) \quad (5)$$

where index *r* refers to region *r*, index *n* refers to the nation as a whole and $\gamma_0=\log(A_r/A_n)$, which represents the difference between regional and national technological progress. Equation (5) implies different responses of output to labour in the region (κ_r) and national (κ_n). All coefficients in (5) can be interpreted as elasticities. This equation is the point of departure in our subsequent specification analysis, which with the existence of diversification and agglomeration economies will be studied empirically for The Netherlands.

The associated model specification of regional labour productivity growth can easily be derived from (5) as

$$\left[\Delta\log(Y_r / L_r) - \Delta\log(Y_n / L_n)\right] = \mu_0 + \mu_{1r}\Delta\log(K_r / L_r) - \mu_n\Delta\log(K_n / L_n) \quad (6)$$

where Δ is the difference operator $\Delta X_t = X_t - X_{t-1}$ and index *t* denotes the period.

3. Data issues and model specification

3.1. Level and growth of regional labour productivity growth

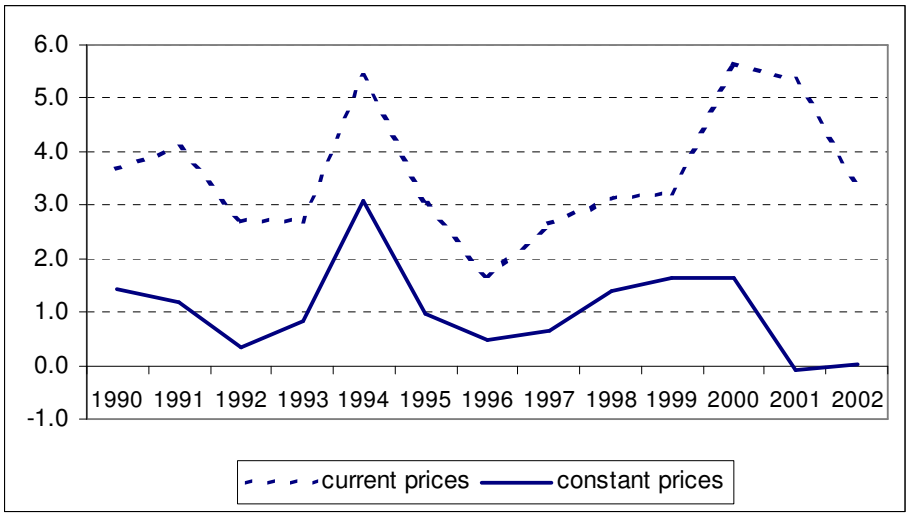
Data sources and definition of the variables are listed in the Appendix. Here we discuss the main features of our data set. Labour productivity is usually measured as GDP per hour worked. However in this study on regions we use the value added per labour year to describe labour productivity.

There are a number of reasons for that. Firstly, we use value added instead of GDP, because GDP figures cannot be fully allocated to each industry in the region but value added can. This industry aspect is essential because there is one industry in one particular region that is omitted throughout this analysis: extraction of natural gas in the region of 'overig Groningen'. Almost 60% of the national value added of the mining sector is attributed to extraction of natural gas in overig Groningen.[4] For more details see the Appendix. Secondly, we use employment in full-time equivalent (fte) labour years because there no statistical information available to derive the total number of hours worked per region before 1995. However, since part-time labour is an important phenomenon in The Netherlands we do want to use a measure of labour input that takes account of this. Therefore we do not use employment in terms of number of persons, but employment in terms of labour years. Unfortunately regional information on employment in labour years is limited to employment of employees only.

This means we abstain from regional labour years of self-employed. Only for agriculture we use employment of both employees and self-employed farmers. The motivation for this is straightforward. Our focal point is to study regional differences and the share of self-employed in the employed labour force is fairly similar between regions. Only agricultural regions have a systematically higher share of self-employed. Therefore we do take account of self-employed in agriculture. An additional reason is that value added of the agricultural industry does include value added of private agricultural enterprises (basically farmers). Since this is the major part of this industry, we should also take the associated employment measure into account when labour productivity is at stake. See also the data appendix.

[4] When oil and gas rigs off-shore are included the share of overig Groningen is still some 35%.

Figure 1 – Percentage growth rate of labour productivity in current and constant prices, The Netherlands, 1990-2001



Source: Statistics Netherlands

A next issue is the time pattern in figure 1 of labour productivity growth in The Netherlands in terms GDP per labour year (of employees and self-employed) in both current and constant prices. In current prices labour productivity growth rates fall in the first half of the 1990's and increase in the second half. In terms of constant prices, however, labour productivity growth is roughly flat in the 1990's averaging 1% with a peak in 1994 and a steep fall after 2000 that marks the current recession.

For analysis of regional productivity growth figures we should be using value added in constant prices. However, the major aim of this paper is to assess and explain differences in both the level and growth rate of regional labour productivity form national. Because of our focus on differences between each region with the national situation, we automatically correct of annual differences in national inflation that are common in each region. Region-specific inflation rates or regional deviations from national inflation are not available.

What can be done is to use national industry prices to construct regional industry price indexes, assuming that regional price differences at an industry level are negligible. Differences in such a regional prices index are entirely determined by regional differences in industry composition. However, our model specification does include a variable that will take account of these differences so transforming the dependent variable will not be necessary.

Figures 2, 3 and 4 show the level (in 1990 and 2001) and the annual growth rate (between 1990-2001) of the Dutch regional labour productivity compared to national. In 1990 the highest levels of labour productivity are found in peripheral regions: the harbours of Zeeuwsch-Vlaanderen and Delfzijl, because of the strong presence of chemical industry, and Zuidoost-Drenthe because of winning of natural oil. In 1996 this oil winning stopped and consequently labour productivity growth ell dramatically to a much lower level in 2001. Value added growth in chemical industry in Delfzijl also dropped substantially compared to national leading to a lower labour productivity in 2001 compared to 1990. Productivity is low in eastern regions like Achterhoek and Zuidwest-Overijssel. Productivity growth rates are particularly high between 1990-2001 in the central regions of Utrecht, Flevoalnd and Veluwe. In the first two regions this is due to a strong growth rate of value added, the latter case is mainly due relatively low employment growth.

Figure 2 – Regional labour productivity 1990

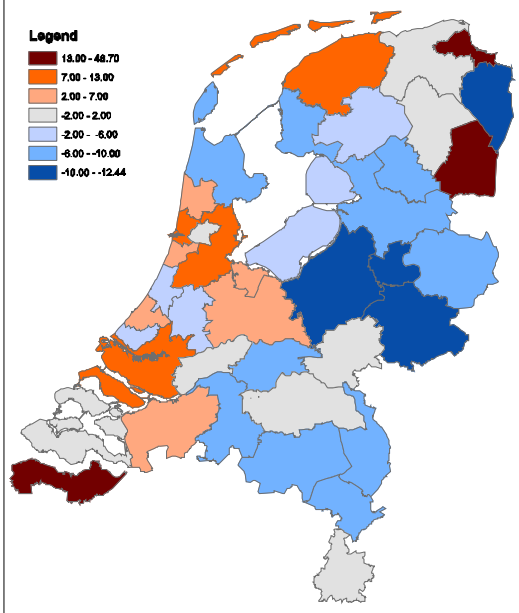


Figure 3 – Regional labour productivity 2001

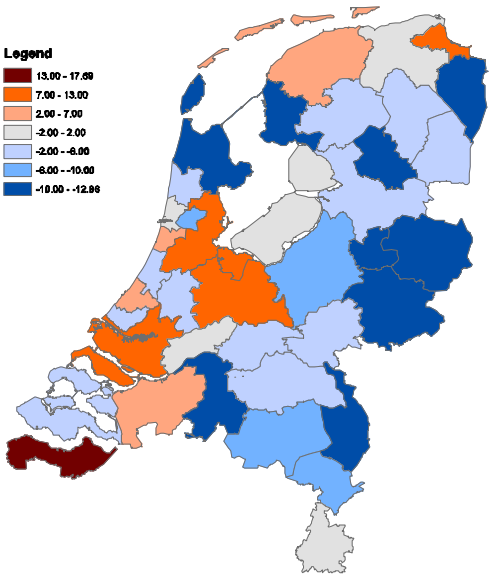
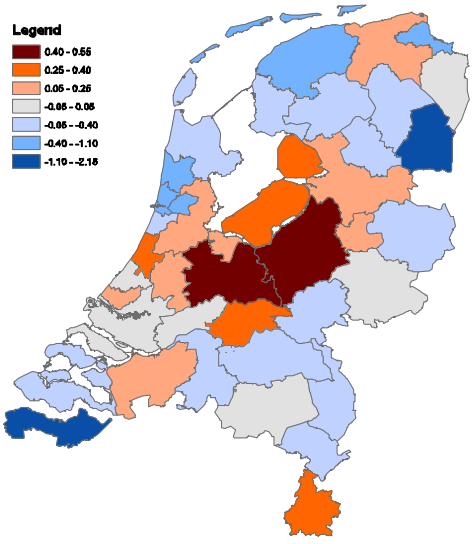


Figure 4 – Regional labour productivity growth 1990-2001



3.2. Explanatory variables

Equation (5) shows that starting-point of our model specification, based on the theoretical notion of a simple production function. However, the theoretical considerations of both spatial and growth economics lead to augmenting (5) with a number of additional explanatory variables that account for these aspects.

As we have seen there are theoretical grounds for the existence of a number of different agglomeration-effects. However, the effect of agglomeration economies can only be assessed by indicators that are indirectly linked to the notion of agglomeration and have strong links among one another and with other explanatory variables. Our aim is to use only explanatory variables that are least correlated among one another, but do have an impact on regional productivity (growth).

In this study we use the following variables to represent agglomeration of a region:

1. *sector diversity*, this represents Jacobs type of urbanisation economies. It measures the extent to which the regional industry structure differs from the national industry structure, assuming this national structure is the optimal diversified economy;
2. *sector localisation*, representing the extent to which sectors in which the region is specialised contribute to regional labour productivity (growth)
3. *knowledge index*, measured as the number of higher vocational and academic students, weighed by their discipline;
4. *job density*, the number of jobs in a region per km^2 land of that region

See the data appendix for more details. We realise that regions are not islands but interact between each other. In order to take account of the fact that a region is influenced by its neighbours, we construct the so-called potential of job density rather than the density itself that pertain to one single region. The potential of a variable X of region r is defined as

$$POT(X_r) = \sum_s X_s \exp(-\beta \cdot t_{r,s}) \tag{7}$$

where t_{rs} is the travel time (or travel distance) between region r and region s and the parameter β is the half time, i.e. the time (distance) it takes to half the effect of X on *POT(X)*.[5] See the data appendix for more details.

Job density is a general measure of urbanisation economies. In terms of model specification (5) it reflects the notion that higher regional job density than national reflects a more efficient use of labour in that region because producers can choose from a larger variety of employees. More general: it reflects the degree of competition, where more competition goes with a higher level (growth) of productivity. The other three indicators of agglomeration are more related to knowledge and knowledge spill-overs and imply a higher regional than national technical progress, or γ_0 in equation (5).

In addition, the level of education of the labour force in a region also reflects the level of knowledge. The larger the share of higher educated in a region relative to national, the higher γ_0 in equation (5) and hence the higher labour productivity. Another important knowledge indicator that is often used in analysis of productivity is innovation, often measured as R&D expenses. Higher R&D also goes with a higher level of γ_0 in equation (5).

Other explanatory variables that reflect the degree of competitive pressure in a region are:

- establishment size,
- share of firm start-ups and firm closures

[5] Notice that this requires a (40×40) matrix of travel tines between all regions.

- export share, measures competitive pressures from international markets
- travel time to both domestic and European mainport areas, measure the distance to important national and international markets and in that sense the degree of competition produces face.

Finally, we come back to the issue of regional differences in (factor) prices and a variable that can take account of these differences. Regional prices that are available are determined by national sector prices weighted by each region's sector structure. Instead of deflating labour productivity (growth) with this sector-weighted price index, we will add a variable that reflects these sectoral differences. This variable is the sectors structure component drawn from a shift-share analysis on productivity and productivity growth. See also Broersma and Oosterhaven (2004) and the data appendix. This regional sector component shows whether sectors that on a national scale have a high level (or growth) of productivity are over- or underrepresented in the region. This over- or under representation is in terms of employment and this is also the weighting factor for regional prices. Therefore adding this sector structure variable (partly) reflects regional prices and by adding this variable deflation can be abstained from.

3.3. Multicollinearity

Before we move to estimating model specification (5), we first want to look at the statistical relation between each of the available explanatory variables and regional labour productivity (growth). Notice that all variables are relative to national. Tables 1 and 2 present the partial correlation coefficient (ρ) for each of the regional variables relative to national for the level and growth of regional labour productivity relative to national, respectively.

The first column of both tables shows the interest of each of the explanatory variables separately on the level of growth of regional productivity. We find a strong partial effect of the regional (growth of the) capital-labour (K/L) ratio relative to the national ratio and of the sector structure and sector localisation.[6]

Tables 1 and 2 also offer information about the mutual correlation between the explanatory variables. In terms of a multiple regression analysis, this mutual correlation might lead to multicollinearity: the different explanatory variables 'explain' nearly the same amount of variation in labour productivity (growth), so that the contribution of each separate explanatory variable becomes unreliable. There is no absolute rule that says when multicollinearity becomes a serious problem. We speak of 'serious' multicollinearity when $|\rho| \geq 0.5$, which is indicated by the shaded cells in tables 1 and 2.

The correlations of table 2 include not just growth rates of variables, but also their level. This is particularly the case for job density, R&D-expenses en the knowledge-index. The latter two variables can be considered as 'investments' in R&D-capital and human capital. This flow character corresponds to growth. Since labour productivity growth equals production growth minus employment growth, this means the sector structure and sector localisation of productivity growth can be subdivided into sector structure and localisation for production growth and employment growth.

[6] This high correlation for the latter two variables comes as no surprise since they both stem from a shift-share analysis on labour productivity (growth).

Table 1. Correlation matrix of regional productivity differences and explanatory variables.

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2	**0.5**	1																			
3	**0.5**	0.0	1																		
4	**0.5**	0.1	**0.5**	1																	
5	0.2	0.3	0.0	-0.3	1																
6	0.3	0.3	-0.1	-0.4	**0.6**	1															
7	0.1	0.1	-0.2	-0.3	0.3	**0.8**	1														
8	0.1	0.1	-0.1	-0.3	0.2	**0.7**	**1.0**	1													
9	-0.3	-0.1	-0.1	0.0	-0.3	**-0.6**	**-0.7**	**-0.7**	1												
10	-0.2	-0.2	0.1	0.2	-0.2	**-0.7**	**-0.9**	**-0.8**	**0.5**	1											
11	-0.1	-0.2	0.0	-0.2	0.0	-0.1	-0.1	-0.1	0.0	0.2	1										
12	0.2	-0.1	**0.5**	0.4	-0.1	-0.2	-0.3	-0.3	0.0	0.3	-0.1	1									
13	0.2	0.1	0.1	0.2	-0.1	-0.2	-0.1	-0.1	0.1	-0.2	-0.2	-0.3	1								
14	0.3	0.2	-0.1	-0.3	**0.6**	**0.7**	**0.6**	**0.5**	-0.4	**-0.6**	0.1	-0.4	-0.1	1							
15	-0.3	-0.2	0.0	0.2	-0.4	**-0.5**	-0.4	-0.3	0.1	**0.5**	0.0	0.4	-0.2	**-0.8**	1						
16	-0.1	-0.1	-0.1	-0.4	0.4	0.4	0.4	0.4	-0.3	-0.3	0.0	-0.1	-0.4	0.4	-0.2	1					
17	0.1	0.0	0.0	-0.3	**0.6**	**0.5**	0.3	0.2	-0.3	-0.2	0.4	-0.2	-0.2	**0.6**	-0.3	0.4	1				
18	-0.1	0.1	-0.2	-0.4	0.3	**0.7**	**0.8**	**0.8**	**-0.6**	**-0.7**	-0.2	-0.4	0.1	**0.5**	-0.4	0.4	0.1	1			
19	-0.1	0.1	-0.3	-0.4	0.3	**0.6**	**0.8**	**0.8**	**-0.5**	**-0.7**	-0.1	-0.4	0.1	**0.5**	-0.3	0.4	0.2	**1.0**	1		
20	0.0	0.0	-0.1	0.1	0.1	-0.2	-0.2	-0.2	0.2	0.1	0.0	-0.1	0.3	-0.1	0.1	0.1	-0.1	-0.1	0.0	1	
21	0.1	0.2	-0.1	-0.2	**0.5**	0.3	0.3	0.3	-0.2	**-0.5**	0.0	-0.3	0.2	0.4	-0.3	**0.5**	0.3	0.4	0.5	0.4	1
22	0.1	0.3	0.0	-0.2	0.4	0.3	0.2	0.2	-0.2	-0.3	-0.2	0.0	0.0	0.2	-0.2	**0.5**	0.1	0.3	0.2	0.2	**0.6**

All variables are denoted as the logarithm of the regional minus the logarithm of the national variable, except for the travel times and diversity-index:

Variable 1	Labour productivity	Variable 12	Export as share of gross production
Variable 2	Sector structure component	Variable 13	Travel time to EU-15 centre of gravity
Variable 3	Sector localisation component	Variable 14	Share of high educated employed labour force
Variable 4	Capital/labour ratio	Variable 15	Share of low educated employed labour force
Variable 5	Establishment size	Variable 16	R&D expenses as share of value added
Variable 6	Job density	Variable 17	Knowledge-index
Variable 7	Potential job density (inc. 'own' region)	Variable 18	Potential knowledge-index per km^2 (inc. 'own' region)
Variable 8	Potential job density (exc. 'own' region)	Variable 19	Potential knowledge-index per km^2 (exc. 'own' region)
Variable 9	Travel time to mainport Rotterdam	Variable 20	Share of new business start-ups
Variable 10	Travel time to mainport Schiphol	Variable 21	Share of newly founded companies
Variable 11	Diversity-index	Variable 22	Share of company closures

Table 2. Correlation matrix of regional growth differences and associated explanatory variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
2	**0.5**	1																								
3	**0.6**	0.2	1																							
4	**0.5**	**0.9**	0.2	1																						
5	**0.7**	0.3	**0.9**	0.3	1																					
6	0.0	-0.2	0.0	0.3	0.0	1																				
7	0.1	0.1	-0.4	0.1	0.2	0.1	1																			
8	**0.6**	0.3	**0.5**	0.4	**0.5**	0.1	0.0	1																		
9	0.1	0.1	0.0	0.3	0.1	0.4	0.0	0.2	1																	
10	0.1	0.1	0.0	0.3	0.1	0.3	0.0	0.1	**0.7**	1																
11	-0.1	0.0	-0.1	0.1	0.0	0.1	0.0	-0.1	-0.1	0.1	1															
12	0.0	0.0	0.0	-0.2	0.0	-0.3	0.0	-0.1	**-0.6**	**-0.7**	0.0	1														
13	0.0	-0.1	0.0	-0.3	0.0	-0.4	0.1	-0.1	**-0.7**	**-0.8**	0.0	**0.5**	1													
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.1	0.1	1												
15	0.0	0.1	0.0	0.2	0.1	0.1	0.0	0.0	-0.1	0.0	0.1	0.0	0.2	0.0	1											
16	0.1	0.2	0.0	0.2	0.1	0.2	0.1	0.1	0.4	0.4	0.0	-0.3	-0.3	-0.1	0.0	1.0										
17	0.0	-0.1	0.0	0.0	-0.1	0.1	-0.1	-0.1	-0.2	-0.1	0.0	0.1	-0.2	0.0	-0.2	-0.4	1									
18	0.1	0.1	0.1	0.3	0.1	**0.5**	0.0	0.2	0.7	**0.5**	0.0	-0.4	**-0.6**	-0.1	0.1	0.4	-0.1	1								
19	0.0	-0.1	0.0	-0.2	0.0	-0.3	0.0	-0.1	-0.5	-0.3	0.0	0.1	**0.5**	0.1	0.0	-0.2	-0.2	**-0.8**	1							
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	-0.1	1						
21	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.3	-0.4	1					
22	0.1	0.1	0.0	0.2	0.1	0.3	0.1	0.1	**0.5**	0.2	0.0	-0.3	-0.2	0.0	0.4	0.4	-0.2	**0.6**	-0.3	0.0	0.0	1				
23	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1			
24	0.1	0.1	0.1	0.3	0.1	0.3	0.0	0.1	**0.7**	**0.8**	0.0	**-0.6**	**-0.7**	-0.1	-0.2	0.4	0.1	**0.5**	-0.4	0.1	0.0	0.1	0.0	1		
25	0.0	0.0	-0.1	0.0	-0.1	0.1	0.0	-0.1	-0.2	-0.2	0.1	0.2	0.1	0.0	0.0	0.1	0.3	-0.1	0.1	0.0	0.0	-0.1	0.0	-0.1	1	
26	0.1	0.1	-0.1	0.2	0.0	0.1	0.0	0.1	0.3	0.1	0.0	-0.1	-0.3	0.0	-0.1	**0.5**	0.0	0.2	-0.2	0.0	0.0	0.1	0.0	0.3	0.2	1
27	0.1	0.1	0.0	0.3	0.0	0.3	0.0	0.1	0.3	0.3	0.1	-0.2	-0.4	0.0	0.0	**0.5**	0.2	0.4	-0.3	0.0	0.0	0.3	0.0	0.4	0.4	**0.6**

All variables are denoted as the logarithm of the regional minus the logarithm of the national variable, except for the travel times and diversity-index:

Variable 1	Labour productivity growth		
Variable 2	Sector structure labour productivity growth	Variable 15	Diversity-index
Variable 3	Sector localisation labour productivity growth	Variable 16	R&D as share of value added
Variable 4	Sector structure production growth	Variable 17	Travel time to EU-15 centre of gravity
Variable 5	Sector localisation production growth	Variable 18	Share of high educated employed labour force
Variable 6	Sector structure employment growth	Variable 19	Share of low educated employed labour force
Variable 7	Sector localisation employment growth	Variable 20	Growth of share of high educated workforce
Variable 8	Growth rate of capital/labour ratio	Variable 21	Growth of share of low educated workforce
Variable 9	Job density	Variable 22	Knowledge-index
Variable 10	Potential job density (exc. 'own' region)	Variable 23	Growth of knowledge-index
Variable 11	Growth rate job density	Variable 24	Potential knowledge-index per km^2 (exc. 'own' region)
Variable 12	Travel time to mainport Rotterdam	Variable 25	Share of new business start-ups
Variable 13	Travel time to mainport Schiphol	Variable 26	Share of newly founded companies
Variable 14	Growth rate export share	Variable 27	Share of company closures

4. Estimation results

4.1. Regional labour productivity level relative to national

When equation (5) is made operational by augmenting it with variables that represent the regional competitive pressure and regional technical progress. Competitive pressure can be represented by:
- export as share of production
- average firm size
- firm dynamics (start-ups, closures)
- distance from (inter)national markets

As a general measure of economies of agglomeration (urbanisation) we add
- job density
- potential of job density (exc. own region)
- potential of job density (inc. 'own' region), as alternative for both

We next include variables that represent the relative technical progress in each region as in μ_0 in (5):
- share of high educated employed labour force
- knowledge institutions
- R&D expenses as share of value added
- sector diversity
- sector localisation

Finally, we add a variable that grasps the differences in regional sector structure from national
- sector structure

All these regional variables are relative to the national average, so equation (5) becomes

$$\left[\log(Y_r / L_r) - \log(Y_n / L_n)\right] = \theta_0 + \theta_1[\log(K_r / L_r) - \log(K_n / L_n)] + \\ + \sum\nolimits_j \theta_{j+1}(\log X_{r,j} - \log(X_{n,j}) \qquad (8)$$

where θ represents the parameters and X represents the additional explanatory variables. Notice we assume one and the same regional and national elasticity for each of the explanatory variables. Note that (8) does not include any regional or time fixed effect dummies, so θ_0 is just an intercept term.

Table 3 shows the estimation results of (8), using data for 40 regions for 1990-2001. Our specification approach is to move from general to specific, but once an adequate specification is established, we do experiment with this specification to assess the effect of agglomeration and diversity. We do want our models to be statistically adequate in that it does not suffer from residual autocorrelation and heteroscedasticity. When our models do reflects these statistical flaws, we can either adapt the specification, e.g. by adding a lagged dependent variable or to use an estimation method that is robust for autocorrelation and heteroscedasticity.

Since our model specification does suffer from both, we start our model approach by calculating the covariance matrix with the robust method of Newey and West (1987). As an alternative we also specified a model including a lagged dependent variable using the heteroscedasticity consistent estimation method of White (1980). This method yields a model with eventually the same explanatory variables as the ones presented here. The major drawback of adding a lagged dependent variable is that formally we need to deflate our measure of labour productivity, because we in fact we explain productivity in year *t* from productivity in year *t-1*. Our aim is to, however, assess and explain the differences in labour productivity between regions and not in time. Therefore the specification analysis presented here is preferable.

Table 3 – Estimation results of regional labour productivity relative to national 1990-2001 for The Netherlands, as in (8).

Explanatory variable	General model	Simplified model	Alternative 1: high education	Alternative 2: knowledge	Alternative 3: potential
Intercept	-0.421	0.012	-0.366	-0.014	-0.031
	(1.712)	(0.907)	(2.584)	(-1.094)	(-2.042)
Sector structure	0.689	0.677	0.784	0.714	0.938
	(3.983)	(4.008)	(4.438)	(4.440)	(6.334)
Sector localisation	0.376	0.462	0.385	0.556	0.617
	(2.273)	(2.969)	(2.209)	(3.162)	(3.454)
K/*L*-ratio	0.283	0.310	0.273	0.297	0.231
	(7.307)	(8.379)	(7.222)	(7.454)	(5.487)
Job density	0.047	0.050	0.026	0.037	
	(3.893)	(6.576)	(3.520)	(5.730)	
Establishment size	-0.070				
	(-1.805)				
High educated workers	0.078		0.089		
	(2.794)		(4.208)		
Low educated workers	-0.053	-0.115		-0.125	-0.176
	(-1.313)	(-4.458)		(-4.621)	(-5.895)
Export	0.038		0.043		
	(2.096)		(2.435)		
Travel time EU-15	0.058		0.066		
	(1.556)		(2.548)		
Diversity index	0.226	0.214	0.187	0.177	0.112
	(2.217)	(2.542)	(2.037)	(1.965)	(1.082)
R&D	-0.011				
	(-1.203)				
Travel time Rotterdam	0.002				
	(0.392)				
Travel time Schiphol	0.021				
	(1.724)				
Knowledge index	-2E-04			-0.145	
	(-0.051)			(-1.043)	
Newly founded firms	-0.011				
	(-0.293)				
Firm closure	0.065				
	(2.475)				
New start-ups	0.029				
	(1.163)				
Potential job density, inc. own region					0.015
					(2.101)
Potential job density, exc. own region		-0.028			
		(-3.619)			
Adjusted R^2	0.741	0.734	0.725	0.719	0.652
Number of observations	480	480	480	480	480
Schwarz criterion	-3.36	-3.44			

Note: between parentheses are the *t*-values based on Newey and West consistent covariance matrix
Schwarz model selection criterion favours model with most negative value.

4.2. Discussion of the results

Our preferred model in the third column of Table 3 accounts for roughly three quarters of the variation in regional labour productivity, which is quite high given the fact that we do not use any fixed effect dummies. The specification in column 3 shows that regional labour productivity level relative to national depends on a number of different variables. First, it strongly depends on variables that represent the composition of the regional industries (sector structure, capital intensity). Second, diversification and agglomeration economies play a vital role (sector localisation, sector diversity, job density, potential of job density). Third, knowledge, in terms of levels of education is also important. These three issues will be addressed below.

Regional sector structure

We find that regional labour productivity is positively affected by the regional sector structure. A positive indicator for the regional sector structure means that industries that, on a national scale, have a high level of productivity are over-represented in the region (or sectors with a low productivity nationally are under-represented). Shifts in industry composition of a region towards industries that nationally have a high productivity will also raise regional productivity levels.

Regional capital intensity

Another important explanatory variable that gives an indication of the regional industry composition is the capital-labour (*K*/*L*) ratio. Some industries are more capital intensive in their production process than others. This variable also has a sound theoretical interpretation as it enters the specification because it is – next to labour – the second production factor in production function (1). The estimated coefficient of the *K*/*L*-ratio can be seen as the capital coefficient in a production function. We find a value of this coefficient of 0.3, so the marginal returns to capital are some 14%, given an output-capital ratio in The Netherlands of 0.48.[7] This compares very well with international research in this area (Peterson, 1989).

Regional sector localisation

Finally, there is also a positive effect of the sector localisation on regional labour productivity. Sector localisation is assumed to represent agglomeration economies; in so far that it gives an indication of regional industry specialisation ('regional clusters'). A positive indicator of sector localisation means that regionally over-represented industries have a higher level of productivity that national (or regionally under-represented industries have a lower than national productivity). In fact this indicator is positive for most regions and the positive coefficient points towards the fact that in general 'regional clusters' do have a positive impact on labour productivity in the region.

Regional sector diversity

Another indicator for agglomeration economies is our diversity index. More diversification enhances knowledge spill-over between firms. When we assume the national industry composition to be the optimally diversified economy, the diversity index measures the extent to which the regional sector structure corresponds to this optimal national structure. The diversity index refers to spill-over effects between companies in different industries.

Regional job density

As a general measure of agglomeration economies, regional job density has a very strong positive effect on labour productivity. The elasticity of job density in the simplified model of Table 3 implies that doubling of regional job density raises regional labour productivity with 5%. This value is very similar to what was found in the literature for the US and some large

[7] Data of the output-capital ration are drawn from GGDC Growth Accounting Database for The Netherlands at http://www.ggdc.net/index-dseries.html#top.

European countries (Ciocone and Hall, 1996, and Ciccone, 2002). This study differs however from these related studies is that fact that we do take account of the effect of neighbouring regions, by considering the potential of job density as an alternative measure of agglomeration. We find that a high job density in surrounding regions mitigates the effect of job density to labour productivity in the 'own' region. A relatively low job density in surrounding regions on the other hand strengthens the effect of job density to labour productivity in the 'own' region.

As far as job density is related to knowledge spill-overs (see section 2), this negative effect has a straightforward interpretation, because densely populated surrounding areas – in terms of jobs – may likely cause knowledge spill-overs for the companies in the own region. In a more general setting: densely populated surrounding areas implies more opportunities for co-operation with companies in those areas, which dims the positive effect that co-operation among companies in the own region has on productivity in their own region.

Education
Knowledge (creation) is usually considered to be important for labour productivity (growth). This is confirmed by the fact that the share of low education labour force in a region enters our preferred model. A relatively small share of low-educated labour goes with a high regional labour productivity, with an elasticity of some -0.12. In other words, more highly educated workers in a region imply higher regional productivity.

In alternative 1 we use the share of high-educated workers per region instead of the share of low educated. This model also yield a adequate specification, but the reason for not choosing it has to do with the fact that the danger of multicollinearity when using the share of high educated is much larger. Table 1 shows that correlations of the share of high educated with other explanatory variables are larger than those of the share of low educated. To avoid problems of multicollinearity we use the share of low educated instead. The interpretation is straightforward. A low level of education implies less use is made of technologically advanced production processes (lower γ_0 in (5)) so production and hence productivity is lower.

Alternative 2 gives the results when a specific knowledge index, based on students in higher vocational and academic institutions, is added. This is to assess the effects of knowledge on regional productivity. We find no significant effect. The same is true (not reported in Table 3) for R&D. Considering the policy interest of stimulating knowledge, this does not have to be a problem, because knowledge is also incorporated in the education level of the employed labour fore, which does have an effect as we have seen. Moreover, R&D and presence of institutions for high and academic education are often characterised as investments (in R&D capital and human capital) and such investments affect the growth rate of productivity rather than its level.

To assess the role of job density in neighbouring regions, we replace job density by its potential (see equation (7)) in the final column of Table 3. This potential also has a significant positive impact, but its effect is much smaller that the effect of job density itself. That gives rise to a possible negative relation between regional productivity and job density in the neighbouring regions (excluding the own region). That is why the potential of job density (excluding the own region) is present in our preferred model. The positive effect of job density on regional productivity is dimmed when surrounding regions are highly dense as well.

Table 4 – Summary of the effects of observed regional-with-national differences in explanatory variables on regional labour productivity relative to national

Explanatory variables	Average absolute difference between regions*	Average effect on regional labour productivity
Sector structure	2.4	1.6
Sector localisation	2.5	1.2
K/*L* ratio	13.5	4.2
Job density	95.4	4.8
Potential of job density	206	-5.8
Share of low-educated work force	11.5	-1.3
Diversity index	4.5	1.0

* The average absolute percentage difference per region with national

Table 4 gives a summary of the estimation results by showing the effect on regional labour productivity when the average absolute observed variation in each of the explanatory variables should occur. The regional sector structure (sector structure indicator and *K*/*L*-ratio) takes account of some 30% of the explained variation of regional labour productivity. Some 20% of the explained differences in regional productivity stems from job density in the region. Overall diversification and agglomeration economies, represented by job density, job density potential, sector localisation and diversity, accounts for 60% of the explained variance of regional labour productivity. So these effects account for a large part of the variation in regional productivity.

4.3. Regional labour productivity growth relative to national

Equation (6) represents the starting point of our model specification for the explanation of regional productivity growth differences. We therefore include the growth rate of the same explanatory variables that we included when explaining regional productivity level differences in the previous section, except for R&D expenses. As argued before, we take this variable as an 'investment in R&D capital' and the flow character of investment relates to growth rather than levels. So taking the growth rate of this investment as explanatory variable is not necessary. We also include the level of some of the other explanatory variables: job density, knowledge index, diversity index and the labour force by education, travel distances. All these variables are fairly constant over time, so taking the growth rate hardly matters.

$$\left[\Delta\log(Y_r / L_r) - \Delta\log(Y_n / L_n)\right] = \zeta_0 + \zeta_1[\Delta\log(K_r / L_r) - \Delta\log(K_n / L_n)] + \\ + \sum_i^k \zeta_{i+1}(\log X_{r,i} - \log X_{n,i}) + \sum_j \zeta_{j+k}(\Delta\log X_{r,j} - \Delta\log(X_{n,j}) \quad (9)$$

Equation (9) gives the operational form of (6) that will be estimated and Table 5 gives the estimation results of (9). Again we want (9) to be free from residual autocorrelation and heteroscedasticity in order to make correct inferences. We move from a general to a specific specification. However, the absence of heteroscedasticity clearly cannot be accepted and autocorrelation cannot irrefutably be denied.[8] Therefore (9) is estimated with the Newey and West (1987) method that yield heteroscedasticity and autocorrelation consistent covariance matrices, like we did with (8).

[8] The Durbin-Watson test indicates no autocorrelation, while the Breusch-Harvey test does.

Table 5 – Estimation results of regional labour productivity growth relative to national labour productivity growth for The Netherlands,1991-2001, as in (9).

Explanatory variables	General model	Simplified model	Alternative 1: education	Alternative 2: potential	Alternative 3: no potential
Intercept	-0.020	-0.004	-0.004	-0.003	-0.002
	(-0.625)	(-3.633)	(-3.553)	(-2.841)	(-2.277)
Sector structure productivity growth		0.715	0.719	0.731	0.718
		(4.854)	(4.867)	(4.943)	(4.834)
Sector structure output growth	0.744				
	(5.411)				
Sector localisation output growth	0.613	0.605	0.605	0.611	0.605
	(7.547)	(7.160)	(7.206)	(7.001)	(7.236)
Sector structure employment growth	-0.726				
	(-2.894)				
Sector localisation employment growth	-0.075				
	(-1.014)				
Growth of *K*/*L*-ratio	0.113	0.116	0.116	0.113	0.115
	(6.188)	(6.367)	(6.397)	(6.083)	(6.367)
Job density	-0.004	-0.006	-0.006		-0.004
	(-3.328)	(-4.333)	(-3.978)		(-3.526)
Growth of establishment size	-0.021				
	(-1.076)				
High educated workers	0.010				
	(1.815)				
Low educated workers	0.022		0.006		
	(2.469)		(1.387)		
Export	0.000				
	(0.030)				
Growth of export	0.030	0.028	0.028	0.029	0.027
	(1.888)	(1.844)	(1.852)	(1.910)	(1.773)
Travel time EU-15	0.005				
	(1.108)				
Diversity index	-0.014				
	(-1.116)				
R&D	0.002	0.002	0.002	-0.000	0.002
	(2.041)	(2.267)	(2.189)	(-1.092)	(2.302)
Travel time Rotterdam	-0.000				
	(-0.357)				
Travel time Schiphol	-0.003				
	(-1.482)				
Knowledge index	0.001				
	(0.793)				
Newly founded firms	-0.009				
	(-0.944)				
Firm closure	0.001				
	(0.240)				
New start-ups	0.003				
	(0.492)				
Potential job density, inc. own region				0.000	
				(0.243)	
Potential job density, exc. own region		0.003	0.002		
		(2.317)	(2.317)		
Adjusted R^2	0.659	0.660	0.660	0.652	0.658
Number of observations	440	440	440	440	440
Schwarz criterion	-5.60	-5.76	-5.75	-5.74	-5.76

Note: between parentheses are the *t*-values based on Newey and West consistent covariance matrix
Schwarz model selection criterion favours model with most negative value.

4.4. Discussion of the results (II)

Our preferred model in the third column of Table 5 accounts for roughly two thirds of the variation in regional labour productivity growth. The model of column 3 shows that the growth rate of regional labour productivity relative to the national growth rate depends on a number of different variables. First, like the model for regional labour productivity level, it strongly depends on variables that represent the composition of the regional industries (sector structure, growth of *K*/*L*-ratio). Second, also diversification and agglomeration economies play a vital role (sector localisation, job density, potential of job density). Third, knowledge, in terms of R&D expenses is important as well.

Regional sector structure

We start our specification analysis by estimating a general model with a large number of explanatory variables, both in levels (when relevant) an in growth rates. We can differentiate between the sector structure of output growth and of employment growth, which together yield the sector structure of labour productivity growth.[9] The hypothesis that the coefficients of the sector structure of output growth and employment growth add up to zero cannot be rejected at any reasonable significance level.[10] Hence in the simplified model we find a significant effect of the sector structure of productivity growth. This means that the more a regional sector structure consists of sectors that nationally have a high productivity growth, the higher productivity growth is in that region.

Regional capital intensity

The growth rate of the capital-labour (*K*/*L*-) ratio also has a strong and positive effect on regional productivity growth. A 1 percentage point increase in the capital intensity of the production process of a region implies a rise in productivity growth of 0.12 percentage points. Like before, this coefficient comes in from the production function we started with, so the growth of capital is an important source for productivity growth.

Regional sector localisation

The sector structure component can also distinguish between a sector localisation component of output growth and one of employment growth (in the general model specification), which together build the sector localisation component of productivity growth. Now the first two components cannot be taken together, since the localisation component of employment growth does not significantly differ from zero. A positive sector localisation of output growth means that regionally over-represented sectors have a higher growth of output than national. The regions that do have a positive localisation of output growth also have higher productivity growth.

Regional job density

We found job density to be a crucial explanatory variable in the model of regional labour productivity levels, so it seems natural to assume that the growth of job density explains a major part of regional labour productivity growth. However, that is not the case. Job density growth effectively equals job growth, since the regional land surface hardly changes. Regional job growth does not affect regional productivity growth, hence constant returns to scale. We do find that the level of job density affects labour productivity growth. A high concentration of jobs in a region has a negative impact on the growth rate of regional labour productivity, but this effect is mitigated when job density in neighbouring regions is taken into account. For the region itself we find agglomeration disadvantages when it concerns growth of labour productivity. However, a high job density in surrounding regions leads to knowledge spill-overs from these surroundings into the region, which can stimulate productivity growth.

[9] The difference between output growth and employment growth equals labour productivity growth.

[10] A standard F-test on this parameter restriction yields F=0.008 .

Export growth
Companies that have witnessed an increase in the export abroad as share of their production are operating on international markets where the competition has increased substantially in recent years due to the trend in deregulation and globalisation. In order to keep up with that increased competition, these firms have been able to raise the effectiveness of the production process. Hence, they have been able to realise high labour productivity growth rates.

R&D
As opposed to the regional productivity level in Table 3, Table 5 shows that in explaining the growth rate of regional labour productivity, a direct measure of knowledge does play a role, in terms of R&D expenses as share of value added. Not only large companies are important when it comes to R&D, but also the presence of universities. The role of R&D (or more generally: innovation) is known to be an important source for labour productivity growth (Donselaar et al. 2003, Jacobs et al. 2002, Guellec et al. 2001, Griliches 2000). Table 5 shows this relation also holds for regional data.

Finally, we also look at some specifications that focus on adding alternative explanatory variables. In alternative 1, we add the share of low educated workers, which did have a (positive) significant impact on productivity. Clearly the labour force by education is correlated with other explanatory variables (Table 2). Alternative 2 shows the effect of replacing job density by its potential. We find a very small but significant effect. This leads to our preferred specification since there appears to be a distinctive difference in the effect of job density itself and the effect of surrounding regions. This second alternative also shows that job density and R&D hang together because in this case the effect of R&D vanishes (Table 1 and 2). Finally, we also consider the specification without a neighbouring effect in the form of a potential of job density. This specification is also acceptable, but is not preferred to our simplified specification in the third column of Table 5.

Table 6 gives a summary of the estimation results by showing the effect on regional labour productivity growth when the average absolute observed variation in each of the explanatory variables occurs. The growth of the regional sector structure (sector structure indicator and growth of *K*/*L*-ratio) takes account of one third of the explained variation of regional labour productivity growth. Some 20% of the explained differences in regional productivity growth stems from job density in the region. Overall diversification and agglomeration economies, represented by job density, job density potential and sector localisation, accounts for 55% of the explained variance of regional labour productivity. So these effects account for a large part of the variation in regional productivity growth. Regional differences in R&D account for only 5% in the explained variance of regional productivity growth.

Table 6 – Summary of the effects of observed regional-with-national differences in explanatory variables on regional labour productivity growth relative to national

	Average absolute difference between regions*	Average effect on regional labour productivity growth
Sector structure lp-growth	0.20	0.14
Sector localisation output gr.	0.36	0.22
Growth of *K*/*L* ratio	4.07	0.46
Job density	95.4	-0.38
Potential job density	206	0.41
Growth export share	3.52	0.10
R&D	43.1	0.09

* The average absolute percentage difference per region with national

5. Sensitivity analysis

Regional productivity level relative to the national level
This section elaborates on the preferred specifications of both the regional labour productivity and regional labour productivity growth. We first move to the preferred specification of the regional productivity level relative to national in Table 3 (column 3) and compare it to a number of alternative specifications in Table 8.

We first split the sample period available in half and do a regression analysis on the first half (1990-1995) and the second half (1996-2001). There are some small differences in the impact of the explanatory variables on regional productivity. The effect of the *K*/*L*-ratio is larger in 1996-2001 than in the period 1990-1995, while that of low educated workers is slightly less. The other parameter values are not significantly different between the two periods. This sample split is likely to be more relevant for productivity growth (see Table 9).

Second, we relax the assumption that causality moves from job density to labour productivity. This causality is derived from the economic theory in section 2, where different types of agglomeration have an effect on output and hence on productivity (and productivity growth). However, it is also thinkable that this causality moves just the other way around, so that high productivity regions have a higher concentration of jobs. This simultaneity problem may also be present for labour productivity and the *K*/*L*-ratio. In order to take account of this problem we re-estimate our preferred specification by GMM.[11]

In order to apply GMM it is necessary to use instruments, *Z*, that are correlated with the explanatory variables *X*, but not with the residuals of the model in (8). When the number of instruments is greater than the number of included explanatory (endogenous) variables, the validity of the instruments can be tested via an over identifying restrictions test. The hypothesis being tested is that the instrumental variables are uncorrelated to some set of residuals and therefore they are acceptable, adequate, instruments. If the null hypothesis is confirmed statistically (that is, not rejected), the instruments pass the test; they are valid by this criterion.

The instrument list we use in our GMM estimation consists of: (regional minus national) land surface, establishment size, travel time to the heart of the EU-15 and of time and region dummies. The over-identifying restriction test on the hypothesis of these instruments being valid yields $\chi^2(36) = 22.66$, which cannot be rejected at any reasonable significance level. The results show that there are no significant differences between the OLS parameters and those of GMM, possible apart from the *K*/*L*-ratio. We do note that Hall and Ciccone (1996) and Ciccone (2002) find a slightly smaller effect of job density when their model is estimated with 2SLS compared to OLS, while in Table 8 we find a higher one. Nevertheless in all cases the differences were small, so simultaneity is not an issue, certainly when agglomeration is concerned.

The last column of Table 8 presents the estimation results when the regional component of labour productivity is used as dependent variable, instead of regional productivity itself. This corresponds to the standard operating procedure when regional labour productivity is studied. Only the true regional productivity, net of regional sector structure, is at stake. This implies that both the sector structure and sector localisation are removed from the model as separate explanatory variables. As a result the adjusted correlation coefficient of this model specification is obviously much less this of our preferred specification. However, the effect of all explanatory variables remains significant and very much in line with the preferred model.

[11] This General Method of Moments estimation method encompasses the more standard instrumental variable methods, like 2SLS, applied by e.q. Ciccone (2002).

Table 8 – Estimation results of sensitivity analysis on regional labour productivity relative to national; equation (8).

Explanatory variable	Simplified model		1990-1995	1996-2001	GMM†	Regional component
Intercept	0.012		0.018	0.014	0.033	-0.001
	(0.907)		(0.960)	(1.251)	(7.676)	(-0.037)
Sector structure	0.677		0.716	0.683	0.707	
	(4.008)		(3.081)	(4.466)	(8.049)	
Sector localisation	0.462		0.450	0.201	0.385	
	(2.969)		(1.980)	(1.624)	(6.129)	
K/*L*-ratio	0.310		0.300	0.441	0.422	0.213
	(8.379)		(5.410)	(15.00)	(21.30)	(5.271)
Job density	0.050		0.058	0.042	0.061	0.039
	(6.576)		(4.983)	(6.311)	(9.500)	(5.258)
Low educated workers	-0.115		-0.188	-0.069	-0.146	-0.093
	(-4.458)		(-4.439)	(-3.328)	(-9.767)	(-3.028)
Diversity index	0.214		0.269	0.220	0.288	0.181
	(2.542)		(2.492)	(3.083)	(11.29)	(1.933)
Potential job density, exc. own region	-0.028		-0.031	-0.022	-0.041	-0.019
	(-3.619)		(-3.002)	(-3.203)	(-7.979)	(-2.111)
Adjusted R^2	0.734		0.699	0.880	0.691	0.381
Number of observations	480		240	240	480	480

† Instruments used – apart from a constant – are (all regional minus national): land surface, establishment size, travel time to the heart of the EU-15, time dummies and region dummies.
Note: between parentheses are the *t*-values based on Newey and West consistent covariance matrix

Regional productivity growth relative to national growth

The main point in the current policy debate is to find instruments that stimulate the growth rate of labour productivity. The reason for this is a slowdown in productivity growth rates in European countries from the second half of the 1990's onwards. This also marks an increasing gap in productivity growth between the USA and Europe (Jorgenson and Stiroh, 2000, van Ark et al., 2002a and 2002b, McGuckin and van Ark, 2004). With increasing globalisation and deregulation of international markets, productivity growth is the tool to enhance competitiveness. Higher productivity growth also leads to growth in the living standards (welfare). Therefore instruments are sought that will get the productivity growth rate back on track.

As a first alternative to the preferred model of Table 5 we split the sample period in half and do a regression analysis on the first half (1990-1995) and the second half (1996-2001). This shows which of the underlying explanatory variables might be responsible to the slowdown of productivity growth in the second half of the 1990's. Table 9 shows that the effect of the *K*/*L*-ratio becomes more important in 1996-2001, while that of all other explanatory variables drops. Only the effect of job density remains unchanged throughout the two periods. Both the growth rate of exports and R&D loose their effect in both periods. The effect of the potential of job density vanished in the second part of the 1990's. This can be explained by the increased commuting, and more generally mobility, in the second half of the 1990's that causes the spill-overs from neighbouring regions, which mitigated the agglomeration disadvantages, to disappear. So by the turn of the century the negative effect of densely populated regions on productivity growth dominates. Estimation of the growth model of Table 5 with GMM essentially yields no different results. Hence, simultaneity is not a large problem as far as our productivity growth model is concerned.

Table 9 – Estimation results of sensitivity analysis on regional labour productivity growth relative to national; equation (9).

Explanatory variable	Simplified model		1991-1995	1996-2001	GMM†
Intercept	-0.004		-0.005	-0.006	-0.004
	(-3.633)		(-3.320)	(-5.548)	(-2.615)
Sector structure productivity growth	0.715		0.741	0.447	0.797
	(4.854)		(3.836)	(3.098)	(3.390)
Sector localisation output growth	0.605		0.746	0.257	0.502
	(7.160)		(6.580)	(6.228)	(4.368)
Growth of *K*/*L*-ratio	0.116		0.083	0.257	0.087
	(6.367)		(4.870)	(8.448)	(2.724)
Job density	-0.006		-0.004	-0.004	-0.006
	(-4.333)		(-2.474)	(-2.170)	(-5.223)
Growth of export	0.028		0.035	-0.001	-0.030
	(1.844)		(1.606)	(-0.046)	(-0.777)
R&D	0.002		0.001	0.001	0.002
	(2.267)		(0.744)	(0.895)	(2.392)
Potential job density, exc. own region	0.003		0.004	0.002	0.002
	(2.317)		(2.440)	(1.347)	(2.323)
Adjusted R^2	0.660		0.692	0.695	0.628
Number of observations	440		200	240	440

† Instruments used – apart from a constant – are (all regional minus national): land surface, establishment size, travel time to the heart of the EU-15 and region dummies.
Note: between parentheses are the *t*-values based on Newey and West consistent covariance matrix

Regional versus national real productivity growth

Finally we take the regional real labour productivity growth rate relative to the national real growth rate. Our motivation for taking productivity growth in nominal terms in Table 5 is that truly regional inflation data are unavailable and regional deflators that could be used are derived from national deflators adapted to the regional industry structure. In other words, rewriting the dependent variable of (9) in real terms yields in simple notation

$$\left[\Delta\log\left(\sum_i a_{i,r}\left(P_{i,0}/P_{i,n}\right)\cdot\left(Y_{i,r}/L_{i,r}\right)\right)-\Delta\log\left(\sum_i\left(P_{i,0}/P_{i,n}\right)\cdot\left(Y_{i,n}/L_{i,n}\right)\right)\right]= \tag{10}$$

$$=\Delta\log\left(\sum_i\left(\frac{a_{i,r}\left(P_{i,0}/P_{i,n}\right)\left(Y_{i,r}/L_{i,r}\right)}{\left(P_{i,0}/P_{i,n}\right)\left(Y_{i,n}/L_{i,n}\right)}\right)\right)\approx\Delta\log\left(\sum_i\left(\frac{Y_{i,r}/L_{i,r}}{Y_{i,n}/L_{i,n}}\right)\right)$$

where the latter term equals the dependent variable of (9), $a_{i,r}$ is the value added share of industry *i* in region *r*, index *n* refers to national variables and ($P_{i,0}/P_{i,n}$) is ratio of the national GDP deflator of industry *i* at time *t*=0 (fixed) and current price at time *t*. So the difference between a specification in nominal terms as in (9) and in real terms as in (10) is determined by the regional production structure. The structure is partly grasped by the sector structure component of the shift share analysis on regional (nominal) productivity growth.[12]

Since this is only an approximation, we will also consider the regional real productivity growth relative to the national real growth rate, despite the data limitations concerning regional prices. In addition, taking the real growth rate is more in line with international

[12] This sector component consists of the difference between the sector component of real value added growth and the sector component of employment growth.

studies, but it also brings about a change in the explanatory variables. The sector structure and sector localisation of (9) were calculated from a shift-share analysis on the nominal regional productivity growth. Since we now move to labour productivity in real terms, the shift-share analysis should now also be redone for real regional productivity growth. Also the growth rate of the regional relative to the national capital-labour ratio will now refer to capital in real terms.

Since regional price deflators reflect the regional sector structure, it comes as no surprise that the elasticities of both sector structure and sector localisation have diminished compared to the model of nominal productivity growth. The same applies to the growth rate of the real *K*/*L*-ratio, while the parameters of all other explanatory variables remained virtually unchanged, apart from the potential of job density. In case of a model of regional real productivity growth we no longer find any influence of the concentration of jobs in neighbouring regions. Hence the negative agglomeration effect dominates as far as real regional productivity growth in The Netherlands is concerned.

Table 10 – Estimation results of sensitivity analysis on regional real labour productivity growth relative to national; equation (9) and (10).

Explanatory variable	Nominal growth model		Growth in real terms	1991-1995	1996-2001	GMM
Intercept	-0.004		-0.001	-0.003	-0.000	0.000
	(-3.633)		(-1.100)	(-2.435)	(-0.490)	(0.042)
Sector structure productivity growth	0.715		0.482	0.766	-0.033	0.708
	(4.854)		(3.174)	(6.082)	(-0.151)	(3.788)
Sector localisation output growth	0.605		0.350	0.612	0.201	0.409
	(7.160)		(4.028)	(4.643)	(2.589)	(3.904)
Growth of *K*/*L*-ratio	0.116		0.078	0.057	0.142	-0.003
	(6.367)		(5.695)	(3.957)	(5.066)	(-0.152)
Job density	-0.006		-0.005	-0.004	-0.005	-0.004
	(-4.333)		(-4.336)	(-2.726)	(-2.561)	(-5.103)
Growth of export	0.028		0.029	0.058	-0.015	-0.031
	(1.844)		(1.613)	(2.493)	(-0.675)	(-1.146)
R&D	0.002		0.003	0.002	0.004	0.003
	(2.267)		(5.206)	(2.688)	(2.930)	(4.682)
Potential job density, exc. own region	0.003		-0.000	-0.002	-0.001	0.000
	(2.317)		(-0.05)	(-1.272)	(-0.840)	(0.339)
Adjusted R^2	0.660		0.332	0.477	0.290	0.224
Number of observations	440		440	200	240	440

† Instruments used – apart from a constant – are (all regional minus national): land surface, establishment size, travel time to the heart of the EU-15 and region dummies.
Note: between parentheses are the *t*-values based on Newey and West consistent covariance matrix

Making the sample split as before, we no longer find any impact of the sector structure in the second half of the 1990's and only a weak effect of localisation. The effect of export growth also vanishes in the period 1996-2001. The real *K*/*L*-ratio on the other hand gets a larger effect on real productivity growth in the latter period, just as the impact of R&D and job density. Can these changes help account for the slowdown in real productivity growth?

In the second half of the 1990's the growth rate of the real *K*/*L*-ratio became negative, i.e. the capital growth rate dropped maybe as a sort of substitution effect due to the abundant growth in employment in those days. This had a depressing effect on productivity growth. In addition the growth of R&D expenses as share of value added also fell in the second half of the

1990's, as a result of the lagging R&D expenses in The Netherlands. This also caused a falling growth rate in labour productivity. Finally, job density increased strongly in the second half of the 1990's as a result of the employment surge. The negative elasticity implies that as a result there was a falling growth rate of productivity. So the drop in the growth rate of Dutch real labour productivity in the second half of the 1990's can be traced back to lagging R&D, lagging capital intensity and rising density in that period.[13]

6. Concluding remarks

This paper has studied the presence of diversification and agglomeration economies for regional productivity and productivity growth in The Netherlands in the 1990's. We do find a substantial diversity and agglomeration effects. These effects account for roughly 60% of the explained variation in regional relative to national labour productivity and about 55% of the regional labour productivity growth, relative to national growth. For regional productivity we found agglomeration advantages in terms of job concentration. High job density in a region gives higher labour productivity. This positive effect is mitigated when job density of neighbouring regions is taken into account.

As far as job density is related to knowledge spill-overs the negative effect of neighbouring regions have can straightforwardly be interpreted. Densely populated surrounding areas – in terms of jobs – may likely cause knowledge spill-overs for the companies in the own region. In a more general setting: densely populated surrounding areas implies more opportunities for co-operation with companies in those areas, which dims the positive effect that co-operation among companies in the own region will have on productivity in their own region.

For regional labour productivity growth relative to national; growth we found agglomeration disadvantages in terms of job concentration. Now high job density in a region has a negative effect on growth, i.e. the costs of a high concentration (like congestion and lack of space) depress productivity growth. However, job density in surrounding regions dims this effect. This interpretation is also quite similar (but opposite): high job density in surrounding regions leads to knowledge spill-overs from the surroundings into the region, which can then stimulate productivity growth in the 'own' region.

The negative relation between job density and labour productivity growth we found may very well be a reflection of the high costs of spatial concentration, like congestion, and hence point towards important agglomeration disadvantages that particularly hamper further productivity growth. This may also explain why the labour productivity growth rate fell in the second half of the 1990's in The Netherlands. In that period employment, and hence job density, grew strongly in particular in the already densely populated western part of The Netherlands. Finally a sensitivity analysis into the different specifications used provides evidence that the original specifications we started with are all fairly robust.

[13] These factors cannot explain the widening gap of productivity growth between Europe and the USA. These are linked to higher intensity of ICT-use and the lower regulatory burden in the USA compared to Europe (McGuckin and van Ark, 2004).

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Appendix: data, sources and definitions

This Appendix describes the sources and definitions of the basic variables that have been used in this inquiry. Most variables are drawn from databases of Statistics Netherlands, available at www.cbs.nl, or from other publications of Statistics Netherlands.

Variable	Source (in Dutch)	Definition / remarks
Value added	CBS, REJ	Value added of mining in the region of 'overig Groningen' is omitted because of the disturbing effect of the extraction of natural gas in that region.
Labour input	CBS, REJ; CBS, Landbouwtelling	REJ: employment volume of employees of companies registered at the Chamber of Commerce. Labour volume of mining in 'overig Groningen' put to zero Landbouwtelling: employment volume of private agriculture companies calculated from the available 5 hour classes of employers and employees These were added to the REJ figures.
Sector structure	Own calculation	Calculated from as shift-share analysis (Broersma and Oosterhaven, 2004)
Sector localisation	Own calculation	Calculated from as shift-share analysis (Broersma and Oosterhaven, 2004)
Capital-labour ratio	CBS, REJ;	The ratio capital/labour is defined as the ratio 'other (capital) income/labour income' in nominal terms, corrected for the regional price of labour and the regional rental price of capital: $(p_K K/p_L L)\times(p_L/p_K) = K/L$ Capital/labour ratio in real terms is constructed by deflating regional capital stocks with national investment prices.
Wage rate	CBS, REJ; CBS, EWL	Wage costs of employees (wages plus social premiums), excluding mining in 'overig Groningen' divided by the number of jobs of employees, excluding mining in 'overig Groningen'. No correction for private agriculture companies.
Rental price of capital	RuG, unpublished series GGDC	
Land surface	CBS, grondgebruik	In km^2
Employed labour force by education	CBS, EBB	Per region: 1996-2001 directly observable 1990-1995 estimated based on provincial and RBA-data
Diversification index	CBS, REJ	$DI = (1- \frac{1}{2} \Sigma_i \lvert w_{ir}/w_r - w_{in}/w_n \rvert) 100\%$ where w_{ir} = labour in sector *i* in region *r* (Oosterhaven et al. 2003, chapter 6). The implicit assumption is that the Netherlands as a whole has the most diversified and for urbanisation economies ideal, industry structure
Production	CBS, REJ	Production of mining in 'overig Groningen' is put to zero

Export	CBS, REJ	1995-1996: export directly observable per region 1990-1994: estimated from provincial data (based on the value added share of each region in the provincial value added). 1997-2001: no longer supplied by Statistics Netherlands, so values the share of export in value added for 1996 were imputed.
R&D expenses	CBS, R&D Survey	1996-2001: R&D of companies, research institutions estimated from provincial data, based on shares of each region in provincial value added. 1996-2001: R&D of universities estimated from provincial data, based on location and type of university, where a technical university has twice the weight of a general university 1990-1995: estimated based on the regional share in provincial value added
Knowledge index	CBS, onderwijsstatistieken	Calculated from number of students of higher vocational and academic institutions, where academics in a technical discipline are weighted with a 3, general academics and technical higher vocational students with a 2 and general higher vocational students with a 1.
Establishments	CBS, Vestigingenregister; CBS, Statistiek van het ondernemingenbestand; CBS, Landbouwtelling	1994-2001: private agriculture establishments added to the establishments from the CBS register 1989-1993 establishments from CBS statistical publication added to agriculture establishments Because both are counted a t January 1 we average two years to get annual averages
Company dynamics (company founding, company closure, new start-ups)	KvK, Bedrijvendynamiek	1994-2001: company founding and closure available 1997-2001: new start-ups available 1990-1993 (1990-1996) impute values of the share of companies in 1994 (1997)
Travel time Schiphol	CBS, bevolkingsstatistieken; www.mapquest.com	Travel time by road from the largest municipality in the region to Amsterdam Schiphol airport by 'mapquest'.
Travel time Rotterdam	CBS, bevolkingsstatistieken; www.mapquest.com	Travel time by road from the largest municipality in the region to Rotterdam harbour ('Erasmusbrug') by 'mapquest'.
Travel time economic gravity point of EU-15	Eurostat, Regiogegevens (GDP en XY coördinaten) op nuts-2 niveau; CBS, bevolkingsstatistieken www.mapquest.com	Calculate gravity point by weighting XY-coordinates with GDP per NUTS-2 region → in the Saarbrücken area. Travel time by road from the largest municipality in the region to Saarbrücken by 'mapquest'.
Potential (of job density and knowledge density)	RuG, (sectie RE), reistijdenmatrix tussen corop-gebieden	Potential of variable X is calculated as $POT(X_r) = \Sigma_s X_s \exp(-\beta t_{rs})$, where t_{rs} is the travel time between region r and region s and β is de 'half time' after 30 minutes travelling.

NOTE: REJ: Regionale Economische Jaarcijfers; EWL: Enquête Werkgelegenheid en Lonen; EBB: Enquête Beroepsbevolking, KvK: (Vereniging van) Kamers van Koophandel; GGDC: Groningen Growth and Development Centre