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3 The Spatial Productivity of Industrial Land
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Abstract

This paper presents a theoretical approach to analysing the concept of spatial productivity and the meaning of land as a production factor in regional science. It presents the results of an empirical study that aims to determine and explain regional differences in the spatial productivity of industrial estates in the Netherlands. It shows that spatial productivity is influenced by urbanisation rates, the share of manufacturing employment on industrial estates and land development policy.

Keywords:

Industrial land, Spatial efficiency, Land policy, Industrial estates

JEL classifications: O18, R12, R14, R52

Introduction

Land plays only a limited role in current economic theory. In classical economics land was the principal source of wealth, but from neoclassical times, economic theory has paid less and less attention to land use, generally regarding it as a production factor of relatively little importance. Having once been the main factor, land faded from the production function. The shift from land to capital and labour inputs was complete by the second half of the 20th century. According to Hubacek and Van der Berg (2002), however, growing interest in sustainable development has triggered a renewed discussion on land use and reintroduced land into the economic discourse.

Concerns about environmental pollution and the depletion of natural resources have provided incentives for new perspectives on, and the conceptualisation of, land in economic analyses, especially in regional and urban economics. In this paper we offer an example of one such 'new' perspective by developing a method that measures just how efficiently industrial land is used. The efficiency of land use is an important issue in spatial planning policies for, amongst others, combating urban sprawl. These policies often refer to the concept of the compact city, which usually implies a combination of increasing mixed-land use and increasing densities. In countries such as the United Kingdom and the Netherlands the supply of land for industrial development has become a matter of increasing concern to many local authorities (Adams et al. 1994; Louw, 2000). It is assumed in those countries that the conditions for economic growth and restructuring can be improved by supplying industrial land, but there is only limited understanding of how the process of land supply and development contributes to meeting the requirements of industrial production at local and regional level. Theoretical and empirical analyses on this subject are scarce (Adams et al. 1994).

In many countries, particularly in densely populated parts of the world such as Singapore, China, Japan and the Netherlands, the promotion of land-use efficiency is a major issue in sustainable spatial planning. Behind the planning rhetoric which connects land-use efficiency,

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3 including land-use density and multiple land-use, with sustainable land-use and sustainable
4 development, there are more pragmatic arguments such as limited land supply (Singapore),
5 high urbanisation rates (China) and increasing urban sprawl (the Netherlands). Whatever the
6 reason for the increasing interest in land-use efficiency, there is relatively little knowledge on
7 how to measure, analyse and compare it. In regional science and economic geography most of
8 the research on spatial efficiency focuses on the location and land-use patterns of economic
9 activities, rather than on the amount of land that is actually used, or as Bapat writes, 'the
10 maximization of spatial activity' (Bapat, 2006: 128). Only the efficiency of agricultural land-
11 use or the productivity of rural land is analysed regularly.

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The few studies which measure and analyse the efficiency of non-agricultural land-use come
mainly from China (Meng et al. 2008; Chen et al. 2007; Maosheng et al. 2008) and Singapore
(Zhu et al. 2002) and were carried out at local or regional level. They offer several indices to
measure land-use efficiencies on economic, social, ecological and environmental dimensions.
Within the economic dimension, employment density is always one of the variables. In the
regional science literature on agglomeration and knowledge spillovers there is clear evidence
that employment density is positively related to economic performance (Ciccone and Hall,
1996; Cervero, 2001; Ciccone, 2002). However, these studies consider all space as equivalent.
Or, as Ciccone (2002: 224) states: '...it was assumed that the density of production is the
same throughout each Nuts 3 region'. It is not possible under such circumstances to treat land
as a distinctive factor of production because it is unknown how much land is used by the
various types of use, including those which do not involve production.

There is therefore a methodological difficulty when it comes to measuring the output created
on land which belongs to different land-use categories. This type of methodological problem
is not unknown in planning (Burton, 2002). In this paper we shall deal with land as a separate
factor of production by introducing a method to calculate the productivity of land that is used
exclusively for economic activities. We define land productivity as the output (added value)

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3 per unit of land. In contrast to the classical economists we omit agricultural land and analyse
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5 only industrial and commercial land which is not mixed with other land-use types. For this
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7 purpose we use data on industrial estates in the Netherlands.
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10 Our research into industrial land in the Netherlands is also embedded in recent planning
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12 debates on industrial estates in the Netherlands. The dissatisfaction with the spatial outcome
13
14 of the public planning and development of industrial land is shared by environmental pressure
15
16 groups and various government agencies (VROMraad, 2006; Segeren et al., 2005). The
17
18 assumption is that spatial productivity on industrial estates is low and that this is a direct
19
20 result of the common strategy by municipalities to supply generous amounts of low-priced
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22 industrial land in order to promote local economic development (Needham and Louw, 2006;
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24 Louw and Bontekoning, 2007; Van der Krabben and Buitelaar, 2007). The land is then
25
26 'spoilt' as it cannot be used anymore for other purposes. This practice also leads to negative
27
28 external effects, such as landscape pollution (Hamers and Nabielek, 2006) and the increased
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30 physical obsolescence of existing industrial estates (Janssen-Jansen, et al., 2008). It is
31
32 assumed that a reduction in the development of industrial estates will increase spatial
33
34 productivity. So far, however, no empirical evidence has been produced to demonstrate a
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36 relationship between the supply of industrial land and spatial productivity in the Netherlands.
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38 In an international context we are aware only of a study by Zhu et al. (2002) in Singapore,
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40 who linked the increase in spatial productivity on industrial estates to the economic policy to
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42 develop new distriparks (which facilitated the restructuring of the Singapore manufacturing
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44 industry and altered the internal structure of firms in their utilisation of space).
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52 In this paper we present data on regional differences in the spatial productivity of industrial
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54 land and we relate spatial productivity to local spatial planning strategies (municipal policies
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56 on industrial land development). Does a generous supply of land reduce spatial productivity?
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58 We measure the land-use efficiency of industrial land in terms of spatial productivity and
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60 analyse regional differences in spatial productivity. In section two we describe how we

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3 calculate spatial productivity. In section three we present our calculated dataset and analyse it
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5 with regression analysis. We conclude with a discussion of our research results and the
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7 usefulness of the concept of spatial productivity.
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15 The calculation of land productivity: methodology

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17 Land – or spatial – productivity is defined here as the monetary added value per unit of
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19 industrial land (usually one net hectare). Industrial land is defined as land that is used
20
21 exclusively for economic activities. To calculate productivity of industrial land it is necessary
22
23 to separate the added value created on industrial land from the added value created on ‘other’
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25 land. We dealt with this by looking at the relative level of employment on industrial land.
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29 Our method to calculate land productivity consisted of four steps (see also Figure 1):
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- 31
32 1. Determine the added value (GDP) per region (40 NUTS-3 regions) and per sector (24
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34 sectors);
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36 2. Determine the location of the employment (industrial estate or elsewhere);
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39 3. Allocate the added value per sector and region to industrial estates;
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- 41
42 4. Determine the land productivity for industrial estates.
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48 (Figure 1 around here)
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54 The added value in a given sector was allocated to the industrial estates in a given region
55 (AVI_{prs}) as:

$$56 \quad AVI_{prs} = E_{prs} * AV_{prs} \quad (1)$$

57
58 and to other land (AVO_{prs}) as:
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60

$$AVO_{prs} = (1 - E_{prs}) * AV_{prs} \quad (2)$$

This implies the use of labour productivity expressed as monetary added value per job to determine the added value on industrial estates. Next, the added value on industrial estates in a given region (AVI_{pr}) was determined as:

$$AVI_{pr} = \sum_{s=1}^S AVI_{prs} \quad (3)$$

and the added value at other locations (AVO_{pr}) as:

$$AVO_{pr} = \sum_{s=1}^S AVO_{prs} \quad (4)$$

Land productivity in a given region (LP_{pr}) was then calculated by dividing the total added value on industrial land in that region by the area occupied by industrial estates in the same region:

$$LP_{pr} = \frac{AVI_{pr}}{S_{pr}} \quad (5)$$

The variables were defined as follows:

AV_{prs} the total added value of a given sector in a given region.

E_{prs} the proportion of employment in a given sector located on industrial estates in a given region.

S_{pr} the total area occupied by industrial estates in a given region.

Indices:

s the index for economic sector, $s = 1$ to S , the total number of economic sectors.

The subscripts:

pr per region.

prs per region and sector.

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3 Data on the added value were available from the national accounts of Statistics Netherlands.
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5 The use of regional and sector data enabled us to take account of industrial and geographical
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7 differences in labour productivity. The data on industrial land were obtained from the Dutch
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9 Integral Industrial Estates Information System (IBIS). For each of the more than 3,500
10
11 existing industrial estates IBIS annually registers, among other things, size, type, area in use,
12
13 disposal of serviced land and location. Not all industrial land is listed in IBIS. For example,
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15 small plots and sites used by only one company as well as fragmented industrial land within
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17 residential areas or Central Business Districts and land use by office parks are excluded.
18
19 Employment data were available from the LISA database, which covers each establishment in
20
21 the Netherlands. Such a detailed level of geographical aggregation ensured that this dataset
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23 was well-suited for a GIS analysis with the spatial data from IBIS in order to determine the
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25 volume and composition of the employment on industrial estates. The output of the GIS
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27 analysis was the level of employment on industrial estates in 24 economic sectors for each of
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29 the 40 NUTS-3 regions in the Netherlands. Land productivity was calculated for 1995, 1999
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31 and 2003.
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41 Three important points should be noted concerning the interpretation of the results:

- 42
43 1. In our calculation we used the average output per job and not the output over a year's
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45 working time, as is common in calculations for labour productivity. The advantage of
46
47 this approach was that the self-employed (for whom there are no data on working
48
49 times) could be included in the calculations. One disadvantage was, however, that we
50
51 had to assume that part-time jobs were equally distributed across industrial estates and
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53 beyond.
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57 2. In our calculations we implicitly assumed that the labour productivity in each sector
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59 on industrial estates was similar to the labour productivity in the same sector outside
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industrial estates. We are not aware of research that assumes otherwise. This also

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3 meant that we could not include the heterogeneity of labour in our analysis: we could
4 not know if and how the characteristics of the labour force on industrial estates were
5 different from other locations. The same was true for capital (or technology) inputs.
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10 There were no data available that distinguished between labour or capital inputs on
11 industrial estates and other locations. That said, one should remember that the regional
12 differences for these inputs at sector level were implicitly included in our calculation
13 (or estimation) of land productivity.
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20 3. In 2001 the calculations for the national accounts were revised. This influenced the
21 added value for the service sectors in particular.
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27 One obvious alternative indicator of spatial productivity is land rents. But one of the problems
28 with this indicator is the shortage of data on prices paid. Secondly, as very little land has been
29 traded recently (compared to the total stock), there are no prices to adequately cover all the
30 land in our analysis. The latter aspect is tied in with the sunk costs of property (including
31 land) investments and the fact that most firms in the Netherlands own their property (Stec
32 Groep, 2005). However, there are also theoretical objections to the use of land rents in the
33 analysis. First of all, rents can only be used as an alternative indicator if land markets are
34 perfect and efficient. In reality, this is hardly ever the case and certainly not in the
35 Netherlands where municipalities have almost a monopoly on the land market and where land
36 values are determined by both political and economic policy considerations. As a
37 consequence, land prices barely reflect the value of land as a production factor (Segeren, et
38 al., 2005; Rebelo, 2009). Or, as Evans (2004:67) puts it: 'The property market is inherently
39 imperfect, so the market only determines a range within which the actual sale price will lie'.
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3 only account for approximately 1% of business investments (Louw, et al., 2009). This also
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5 puts the question of endogeneity into perspective.
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10 11 12 The productivity of industrial land in the Netherlands

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15 Despite mounting concern about their impact on the national landscape, industrial estates
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17 occupy only a small part of the total surface of the Netherlands. In 2003 they accounted for
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19 2.3%, but this figure has risen rapidly, from only 2.0% in 1995. Employment on industrial
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21 estates increased between 1995 and 1999 from 29.1% to 31.9%. In 2003 it fell to 31.7%, a
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23 modest decrease, possibly explainable by the economic recession. A similar trend is
24
25 discernible in the percentage of added value produced on industrial estates, which is slightly
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27 higher than the percentage of employment (also Table 1). The net and gross spatial
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29 productivity of industrial estates have both increased over the years. These figures show
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31 beyond doubt that industrial estates are important to the Dutch economy.
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41 (Table 1 around here)
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48 The rest of the paper is devoted entirely to an analysis of the net spatial productivity, because
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50 the net area is the amount of land that is designated as industrial land. Figure 2 shows the
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52 regional differences in the productivity of industrial land. In 2003 s-Gravenhage (The Hague)
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54 with €8.9 million per hectare, topped the list for spatial productivity while Oost Groningen
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56 (East Groningen) came bottom with €0.8 million. Although land productivity has increased
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58 over the years in most regions, the order from top-to-bottom has remained almost unchanged
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60 (see Figure 2), thus indicating stable regional patterns. Figure 3 shows a map of the regional

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3 differences in net spatial productivity in 2003, which clearly indicates that the highest spatial
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5 productivity occurs in the most urbanised regions in the western part of the Netherlands (the
6
7 Randstad). The Rotterdam region (Groot Rijnmond) appears to be the exception to this
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9 general picture, with a spatial productivity of € 2.0 million per hectare, which is modest
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11 compared with other regions in the Randstad (see also Figure 2). The map in Figure 3 also
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13 shows that the regions with the lowest spatial productivity lie in the peripheral regions of the
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15 Netherlands, with the regions in between showing modest spatial productivity.
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22 (Figure 2 around here)
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27 (Figure 3 around here)
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32 How can we explain the regional differences in spatial productivity on industrial estates? We
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34 drew a distinction between variables relating to spatial planning strategies (our main
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36 objective) and two general variables which we used as control variables. The first of the
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38 policy-related variables was the supply of industrial land. Needham and Louw (2006) suggest
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40 that a high supply of industrial land in the Netherlands results in low spatial productivity. In
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42 regions with a high demand for land and low levels of supply one would expect the price of
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44 industrial land, and hence, the land productivity to be high. Unfortunately, we were not able to
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46 test this relationship empirically, because of the absence of reliable data on the prices of
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48 serviced industrial land on industrial estates. The only price data in IBIS, the national
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50 database on industrial estates, are the 'asking prices' set by the suppliers which, in most cases,
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52 probably exceed the selling prices (the prices companies actually pay for their land).
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54 However, we could still measure the scarcity of land by calculating regional differences in the
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56 supply-demand ratio. We defined supply as the area of building land on industrial estates that
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58 was immediately available to companies in a particular year. The demand was the
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3 accumulated area of land on industrial estates that was issued to companies up to that same
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5 year. Because Needham and Louw (2006) assume that past policies influence current land-
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7 use, we used a supply-demand ratio from the past (1988) and the three years for which we
8
9 calculated the spatial productivity (1995, 1999 and 2003).
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12 The second policy-related variable was the percentage of jobs in a region located on industrial
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14 estates. A high percentage of jobs on industrial estates in a region would indicate that in the
15
16 past there had been (and probably still was) a spatial policy that favoured the development of
17
18 industrial estates. If the assumption in the introduction is right, a negative relationship should
19
20 exist between the percentage of employment on industrial estates and spatial productivity.
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24 The third policy-related variable was the presence of physically obsolete industrial estates. In
25
26 Dutch policy debates it is argued that due to the development of many new industrial estates,
27
28 companies find it more efficient to relocate than to invest in their current properties. This
29
30 implies that older estates are characterised by low employment densities due to many vacant
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32 premises and the presence of marginal operating companies which cannot afford to relocate. It
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34 was therefore expected that a region with a high share of obsolete industrial land would have
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36 a low level of spatial productivity. These data were only available for 2003.
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43 Besides these policy-related variables there were other variables that we wanted to control for.
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45 Louw and Bontekoning (2007) suggest that regional variations in sector composition on
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47 industrial estates could be an explanation. Different branches of industry require different
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49 amounts of land. Service sector companies, for example, require only a limited amount of
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51 space for each job and are accommodated in multi-storey office buildings, whereas
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53 manufacturing companies use single-storey buildings. Some manufacturing sectors such as
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55 refineries, chemical plants and transport require large areas of land. The variations in sector
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57 composition on industrial estates should therefore influence employment densities which
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59 should, in turn, influence spatial productivity. A high share of service sector employment was
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3 expected to increase spatial productivity, whereas a high share of manufacturing sector
4 employment was expected to decrease spatial productivity. Because these variables were
5 significantly correlated we only applied the share of manufacturing employment.
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10 A second plausible explanation for the regional differences was the difference in regional
11 employment densities. Ciccone and Hall (1996) showed that, due to agglomeration effects, an
12 increase in employment densities has a positive effect on the average labour productivity.
13 Intriguing in this respect is that regional differences in labour productivity in the Netherlands
14 (see Broersma and Van Dijk, 2005) are relatively small compared with regional differences in
15 land productivity. This suggests that regional differences in labour productivity as such have
16 no significant influence on land productivity, and that differences in land use are therefore
17 more important. Since industrial estates are part of the regional economy and cannot be seen
18 as isolated sites, we applied the regional urbanisation rate (average number of addresses per
19 sq kilometre in a region) instead of the employment densities on industrial estates (1).
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34 Other variables such as proximity to markets or a general measure of access were not included
35 because of the limited number of regions we could use in our analysis (see below). Moreover,
36 we did not compare the spatial productivity of individual estates, but we did compare the
37 average spatial productivity of estates by region. It was likely that access to markets would
38 have an influence mainly at the level of individual estates in relation to local markets, rather
39 than in relation to regional or national markets.
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53 (Table 2 around here).
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57 Table 2 provides descriptive statistics for the variables we used in our analysis. The fact that
58 the mean, range and standard deviation are much higher for the supply-demand ratio for 1988
59 than for the supply-demand ratios for 1995, 1999 and 2003 stems from differences in the IBIS
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3 database. In 1988 only estates with a minimum size of five hectares were included in the
4
5 database. In the other years the minimum size was one hectare. This has scarcely any
6
7 influence on the size of the supply as most of the industrial land supply is on estates larger
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9 than five hectares. However, the accumulated amount of land issued to companies in 1995
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11 was 2.6 times higher than in 1988. So the mean, range and standard deviation for 1988 are
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13 higher than for the other three years. The IBIS database for 1988 reflects its original purpose,
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15 namely, to monitor the supply of industrial land, whereas in the 1990s the purpose was to
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17 monitor the stock of industrial land.
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24 To find empirical evidence for the relationship between net land productivity and the
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26 independent variables described above, we estimated ordinary least squares (OLS) models for
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28 1995, 1999 and 2003. We analysed only net land productivity because this was the amount of
29
30 land used by firms. Multi-collinearity was checked by analysing correlations between the
31
32 independent variables. In 1995 and 1999 a significant correlation was found at the 1% level
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34 between the urbanisation rate and the share of manufacturing employment. In 2003 a
35
36 significant correlation was found between these variables at the 5% level. The same levels of
37
38 significance applied for the correlation between the supply-demand ratios for 1988 and
39
40 1995/1999 and 2003. In the 2003 dataset a significant correlation at the 1% level was found
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42 between the supply-demand ratio for 2003 and the share of obsolete estates. These variables
43
44 were, however, included in the analyses because the variance inflation factor (VIF) for these
45
46 variables in all of the models was below 2.5. According to Field (2000) multi-collinearity
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48 becomes a problem if $VIF > 10$.
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53 There is also the issue of spatial autocorrelation. Although this is highly relevant in regional
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55 science when regional differences are analysed in the form of an OLS model, we argue that it
56
57 was not appropriate to include spatial autocorrelation in our analysis. The reason for this is
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59 that we were not dealing with continuous space but with many discontinuous spaces in the
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3 form of industrial estates within a region. These approximately 3,500 estates accounted for
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5 only 2.3% (2003) of the total surface area of the Netherlands and were scattered all around the
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7 country in both urban and rural areas. Spatial concepts such as distance-decay, spatial
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9 interaction, and spatial randomness, which form the theoretical foundation of spatial
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11 autocorrelation and which assume continuous space, did not apply to our data. On these
12
13 theoretical grounds the inclusion of spatial autocorrelation could be justified only if the
14
15 analysis was executed on the scale of individual industrial estates. Our aggregated data were
16
17 not, however, suitable for calculating land productivity on this spatial scale. Moreover, given
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19 the relatively small size of individual industrial estates, it would be unrealistic to assume that
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21 they would have a significant influence on other estates in the region, let alone on estates in a
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23 neighbouring region (2).
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29 Because we were primarily interested in the relative importance of the independent variables
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31 and the direction of the associations, only standardised parameters are presented here (Tables
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33 3, 4 and 5). In all of the models the control variables have the expected signs. Regional
34
35 urbanisation rates are positively related to spatial productivity and the level of manufacturing
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37 employment is negatively related to spatial productivity. Also, both control variables are
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39 highly significant. Only the share of manufacturing in the 2003 models is significant at the
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41 5% level instead of the 1% level in the 1995 and 1999 models. This slight drop in significance
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43 is probably tied in with the general decline in the level of manufacturing employment on
44
45 industrial estates (see Table 2). It is clear from the standardised betas that in all of the models
46
47 the urbanisation rate has the largest effect on the spatial productivity of the two control
48
49 variables. This finding is consistent with the findings of Ciccone and Hall (1996), Ciccone
50
51 (2002) and more general knowledge about urban economics: high densities go hand-in-hand
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53 with intensified land use.
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59 Among the policy variables only the supply-demand ratio for 1988 is significant and has the
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expected sign in all of the models for every year (Equations 1 in Tables 3, 4 and 5). That

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3 means that a high supply-demand ratio in 1988 led to lower spatial productivity in 1995, 1999
4 and 2003. The supply-demand ratios for 1995, 1999 and 2003 (Equations 2 in Tables 3, 4 and
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7
8 5) have a less uniform effect on spatial productivity. Only in the 1995 and 1999 models does
9
10 this variable show the expected negative sign and then it is only significant in 1999. In the
11
12 2003 model the supply-demand ratio is positively related to spatial productivity but is not
13
14 significant (Equation 2 in Table 5). These findings imply that past supply-demand ratios have
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16 more effect on spatial productivity than recent supply-demand ratios. This may be due to the
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18 high level of supply-demand ratios in 1988 compared with 1995, 1999 and 2003 (see Table
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20 2), which is mainly due to differences in the IBIS database.
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27 (Tables 3-5 around here)
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32 The share of regional employment on industrial estates is, as expected, negatively related to
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34 spatial productivity (Equations 3 in Tables 3, 4 and 5). This effect is not significant, as shown
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36 in Equation 3 models of Tables 3, 4 and 5. However, in the overall model for 1999 (Equation
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38 4 in Table 4) the share of employment on industrial estates is significant while both supply-
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40 demand ratios are not.
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43 In the 2003 model the share of obsolete industrial land does not, as expected, have a negative
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45 effect on spatial productivity. The correlations between this variable and the urbanisation rate
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47 and supply-demand ratios for 1988 and 2003, which are negative, seem to suggest a
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49 relationship other than was expected. A large number of physically obsolete industrial estates
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51 does not necessarily imply low spatial productivity at regional level. The above-mentioned
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53 rationale behind the expected negative sign may not even be valid since there is a significant
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55 positive correlation between the share of obsolete industrial land and the urbanisation rate and
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57 a significant negative correlation with supply-demand ratios for both 1988 and 2003,
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3 suggesting that the degree of obsolescence may have been caused by an under-supply rather
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5 than an over-supply.
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10 By comparing the regression coefficients in the various models we can see how 'stable' the
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12 influence of that variable is over time. This is particularly relevant for the supply-demand
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14 ratio for 1988 given that it is insignificant in the overall model for 1999 (Equation 4), but
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16 significant in the 1995 and 2003 models. We compared the non-standardised coefficients in
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18 the models with each other – thus checking for stability over time – using the Confidence
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20 Interval for Difference (Cohen et al., 2003: 46-47). We applied this technique to models
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22 containing four variables: both control variables, the supply-demand ratio 1988 and the share
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24 of employment on industrial estates. The analysis revealed no significant difference between
25
26 the regression coefficients of these variables between the 1995, 1999 and 2003 models.
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30 Accordingly, our analysis of the regional differences in spatial productivity on industrial
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32 estates provides empirical evidence for the hypothesised relationship between the historical
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34 supply-demand ratio and spatial productivity. This is confirmed by Equation 4 in Table 3 and
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36 Equation 5 in Table 5. Using all policy variables simultaneously results in significant
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38 estimates for this policy variable in 1995 and 2003. In the 1999 model only the share of
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40 employment on industrial estates was significant, but the analyses with the Confidence
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42 Interval for Difference between the regression coefficient indicated that the coefficients
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44 themselves showed no significant difference between the models. Both control variables have
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46 a significant effect on spatial productivity. Taking the magnitude of the standardised
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48 coefficients of these variables into consideration, their effect on the spatial productivity is
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50 greater than the supply-demand ratio.
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Discussion

There is a small but growing scientific interest in land-use efficiency. However, as neither regional science nor economic geography has examined this subject in great detail, economic arguments cannot be confidently applied in spatial planning debates. It is for this reason that we developed a method to calculate the spatial productivity for industrial land. The results revealed significant regional differences in the spatial productivity of land on industrial estates in the Netherlands. It is high in urbanised regions and low in peripheral regions – which could be expected from studies about employment densities. The regression analysis showed that spatial productivity correlates negatively and significantly with the proportion of manufacturing jobs on industrial estates and the supply-demand ratio for 1988. The negative correlation between this historical supply-demand ratio and spatial productivity indicates that the way in which industrial estates are planned and developed in the Netherlands does influence spatial productivity: an abundant supply of industrial land reduces spatial productivity on industrial estates. Moreover, it suggests – within the constraints of our dataset – that a reduction in the supply of industrial land would increase productivity on that land. The political consequences of this outcome are significant in the Dutch context. It appears that government intervention to reduce the development of industrial estates is unlikely to impede regional economic growth, but will rather result in increased spatial productivity on industrial estates. More recent lower supply-demand ratios do have a negative effect on spatial productivity but this is not significant for all the models. It may therefore be assumed that recent supply-demand ratios do not have a substantial effect on spatial productivity anymore.

Our research findings seem to confirm the existence of agglomeration economies. It cannot, however, be concluded that agglomeration effects occur on individual industrial estates, since our calculations are based on aggregated data about labour productivity on industrial estates. A study by De Vor and De Groot (2010) shows that there is hardly any sign of agglomeration

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3 externalities on the scale of industrial estates. Agglomeration effects most probably exceed
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5 this local geographical scale.
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10 In policy terms, the concept of spatial productivity is relevant to debates about the efficient
11 use of scarce land. Information on (regional differences in) industrial land productivity can be
12 particularly valuable in countries and regions where there is strong pressure to develop
13 available land. The regression analysis in this paper shows that differences in land
14 productivity can be partly explained by policy-related variables, which suggests that the level
15 of spatial productivity of industrial land in a given region can be influenced.
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24 The usefulness of the concept of spatial productivity must be considered theoretically as well
25 as in policy terms. By using spatial productivity we treated land as if it were an independent
26 production factor like labour. As in the calculations for labour productivity, we allocate all the
27 added value to one production factor, in our case, land. However, the trend in economics over
28 the last century has been to combine land with capital, effectively condensing the production
29 factors to only labour and capital. The underlying logic for this practice is that land does not
30 actually participate in industrial production, as it does in agriculture. Land is a necessity for
31 industrial production but, contrary to other production factors, it is not worn out or
32 transformed in the process.
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45 As a production factor land has two attributes: location and the size of the production site
46 (Alonso, 1964). According to Hubacek and Vazques (2002), producers usually take
47 proportionate decisions between land and other factor inputs, when deciding on long-term
48 investments. In the short term producers cannot substitute land for other factor inputs, because
49 land is a quasi-fixed factor of production. Therefore, in the short-term resource allocation
50 takes place *on* land, without considering land as a factor in the production process itself. By
51 measuring spatial productivity we determine how much added value is created by different
52 decisions on resource allocation (including capital, labour, knowledge and location) on a
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3 particular amount of land. Therefore, land use in manufacturing and services is not a
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5 production factor in the strict sense of an input, as in agriculture. However, land, in terms of
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7 land use, is a necessary condition for production. Analysing spatial productivity therefore
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9 helps to improve our knowledge of the allocation process of production factors on land and
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11 the efficiency of this process and thus contributes to discussions about sustainable land use.
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Notes

1. Employment densities on industrial estates correlates highly with spatial productivity (pearson correlation 1995: 0.958; 1999: 0.968; 2003: 0.966) because these densities are implicitly used in the calculation of spatial productivity. Using the employment densities on industrial estates to explain regional differences in spatial productivity yields high R²: 1995: 0.807; 1999: 0.891; 2004: 0.891). The unexplained variance is then due to regional differences in labour productivity.
2. This can also be derived from research by Dunse et al. (2005), who found that rent gradients for industrial property were very shallow near CBDs or short distance gradients near motorway junctions.

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Figure 1 Four steps to calculate land productivity

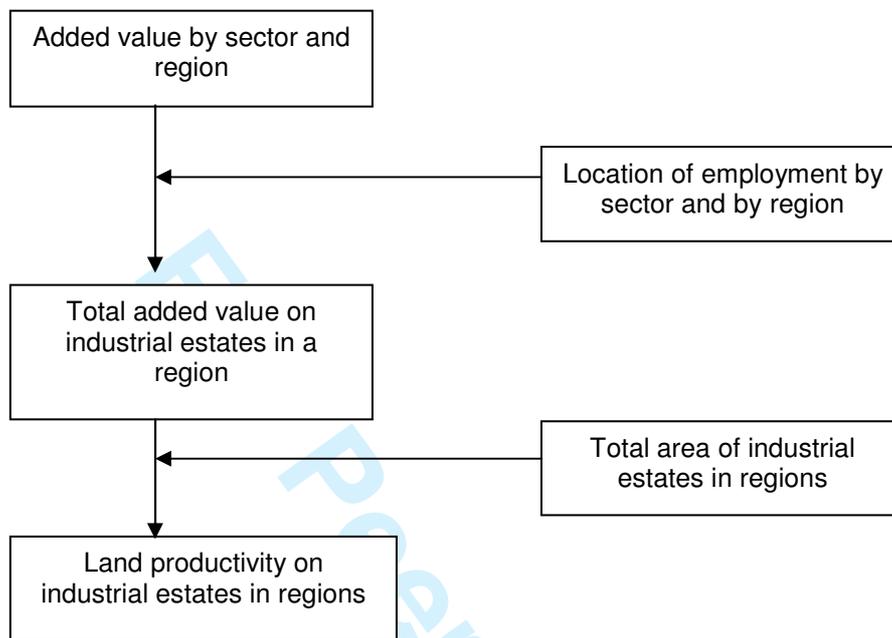


Table 1 Some descriptive statistics on Dutch industrial estates.

	1995	1999	2003
Number of industrial estates (end of year)	3,344	3,542	3,673
Area of industrial estates in ha (gross)*	81,659	89,529	94,647
Area of industrial estates in ha issued to firms**	48,023	54,883	59,198
Share of employment on industrial estates	29.1%	31.9%	31.7%
Share of added value on industrial estates	30.4%	32.9%	32.8%
Average net spatial productivity (million € / ha)	1.76	2.05	2.34
Average gross spatial productivity (million € / ha)	1.35	1.55	1.76

* The gross area includes roads, harbours, green space, etc. The net area is the number of ha used by firms and the supply.

** This does not include the net area which has not yet been issued to firms.

Table 2 Variable means, range and standard deviations for 1995, 1999 and 2003 in the 40 regions.

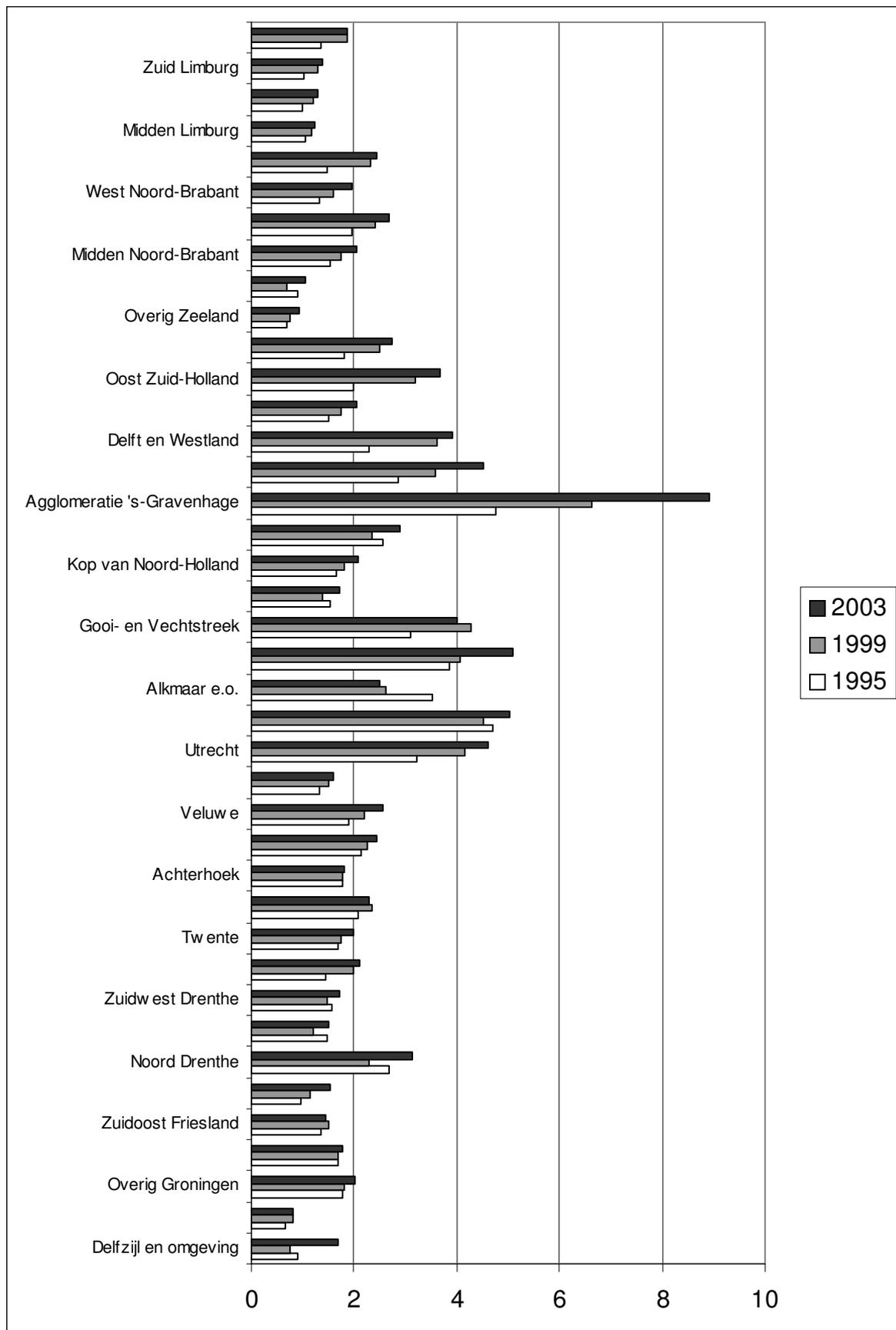
	mean	range	standard deviation
1995			
Net spatial productivity	1.99	4.07	1.02
Share manufacturing jobs	42.29	54.59	12.54
Urbanisation rate	1374.93	4028.00	848.51
Share of jobs on industrial estates	31.14	28.35	6.81
Supply-demand ratio 1988	41.37	149.89	26.95
Supply-demand ratio 1995	15.04	51.24	12.10
1999			
Net spatial productivity	2.20	5.91	1,23
Share manufacturing jobs	37.85	41.17	10.91
Urbanisation rate	1394.45	4107.00	865.96
Share of jobs on industrial estates	32.93	26.93	6.76
Supply-demand ratio 1988	41.37	149.89	26.95
Supply-demand ratio 1999	10.38	44.30	9.80
2003			
Net spatial productivity	2.53	8.10	1.51
Share manufacturing jobs	34.26	41.98	10.70
Urbanisation rate	1359.18	3336.00	708.57
Share of jobs on industrial estates	32.86	25.52	6.26
Supply-demand ratio 1988	41.37	149.89	26.95

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Supply-demand ratio 2003	10.96	41.61	9.99
Share of obsolete estates	32.99	77.27	17.84

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Figure 2 Net land productivity on industrial estates per region in 1995, 1999 and 2003
(x € mln / ha).



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Figure 3 Net land productivity on industrial estates in regions in 2003 (x € mln / ha).

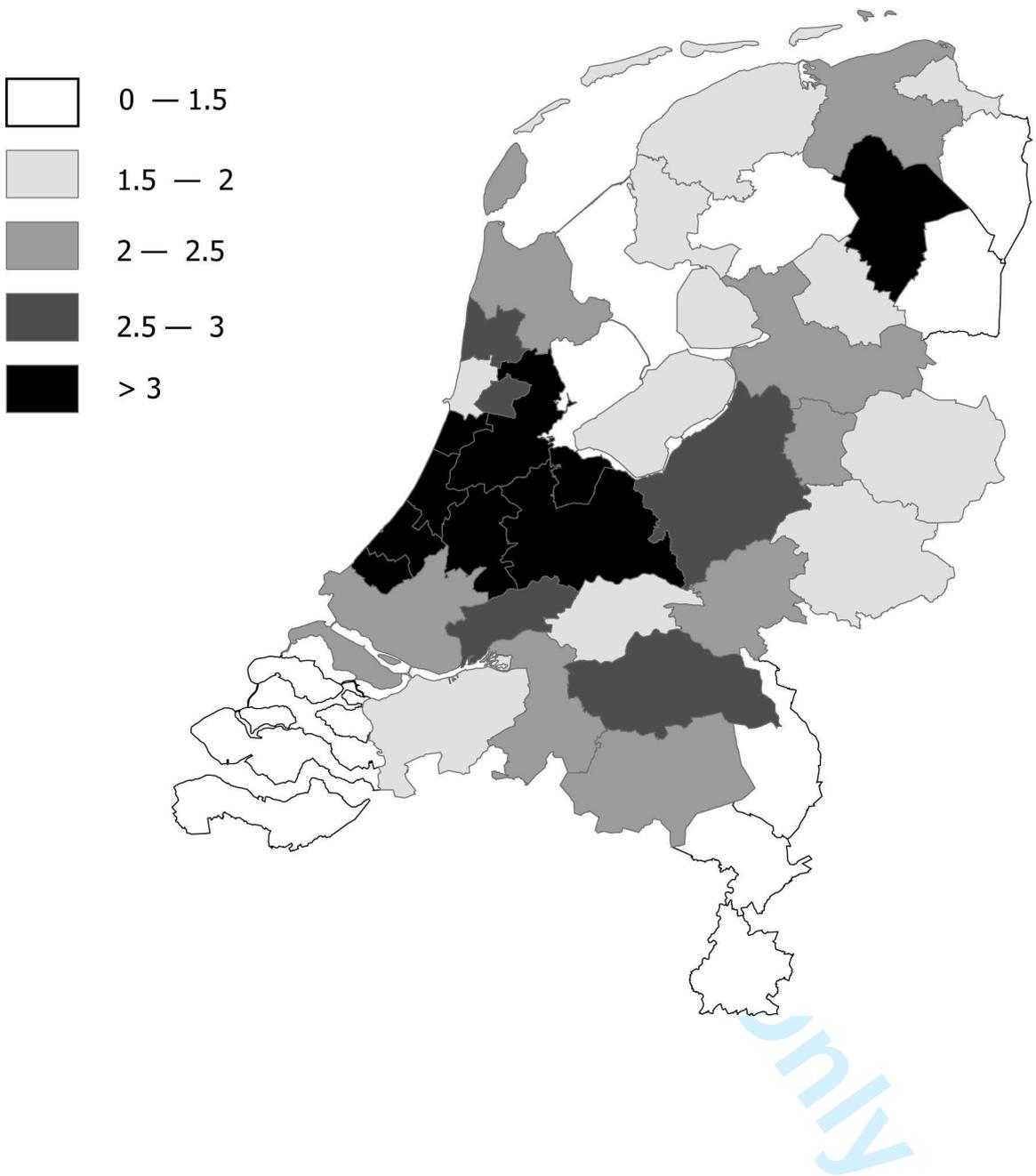


Table 3 Regression analysis for net land productivity in 1995 in the 40 regions
(standardised betas).

	(1)	(2)	(3)	(4)
Urbanisation rate	0.50***	0.48***	0.48***	0.48***
	(4.21)	(3.85)	(3.63)	(4.01)
Share manufacturing employment	-0.36***	-0.34**	-0.29***	-0.37***
	(-3.05)	(-2.64)	(-3.03)	(-3.02)
Supply-demand ratio 1988	-0.26***			-0.35**
	(-2.80)			(-2.51)
Supply-demand ratio 1995		-0.16		0.07
		(-1.54)		(0.52)
Share employment on estates			-0.04	-0.12
			(-0.40)	(-1.24)
F	26.37***	21.60***	19.64***	16.18***
Adjusted R ²	0.66	0.61	0.59	0.66

t-values in parentheses.

*** significant at the 1% level.

** significant at the 5% level.

Table 4 Regression analysis for net land productivity in 1999 in the 40 regions
(standardised betas).

	(1)	(2)	(3)	(4)
Urbanisation rate	0.48***	0.42***	0.43***	0.40***
	(4.07)	(3.49)	(3.19)	(3.39)
Share manufacturing employment	-0.39***	-0.43***	-0.43***	-0.40***
	(-3.35)	(-3.57)	(-3.25)	(-3.52)
Supply-demand ratio 1988	-0.27***			-0.24
	(-3.21)			(-2.01)
Supply-demand ratio 1999		-0.24***		-0.11
		(-2.74)		(-0.95)
Share employment on estates			-0.11	-.020**
			(-1.14)	(-2.31)
F	34.66***	31.85***	25.59***	24.25***
Adjusted R ²	0.72	0.70	0.65	0.75

t-values in parentheses.

*** significant at the 1% level.

** significant at the 5% level.

Table 5 Regression analysis for net land productivity in 2003 in the 40 regions (standardised betas).

	(1)	(2)	(3)	(4)	(5)
Urbanisation rate	0.61***	0.65***	0.62***	0.55***	0.58***
	(5.39)	(5.13)	(5.14)	(4.11)	(4.69)
Share manufacturing employment	-0.28**	-0.28**	-0.27**	-0.34**	-0.29**
	(-2.53)	(-2.26)	(-2.21)	(-2.65)	(-2.37)
Supply-demand ratio 1988	-0.20**				-0.26***
	(-2.44)				(-2.91)
Supply-demand ratio 2003		0.04			0.16
		(0.44)			(1.69)
Share employment on estates			-0.08		-0.12
			(-0.89)		(-1.48)
Share obsolete				0.12	0.10
				(1.21)	(0.97)
F	37.99***	31.15***	31.86***	32.67***	21.47***
Adjusted R ²	0.74	0.70	0.70	0.71	0.76

t-values in parentheses.

*** significant at the 1% level.

** significant at the 5% level.