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To cite this version:
Erik Louw, Erwin van Der Krabben, Hans Van Amsterdam. The Spatial Productivity of Industrial Land. Regional Studies, Taylor & Francis (Routledge), 2011, pp.1. <10.1080/00343404.2010.530250>. <hal-00670738>

HAL Id: hal-00670738
https://hal.archives-ouvertes.fr/hal-00670738
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The Spatial Productivity of Industrial Land

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(Received June 2008: in revised form August 2010)
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,
including land-use density and multiple land-use, with sustainable land-use and sustainable
development, there are more pragmatic arguments such as limited land supply (Singapore),
high urbanisation rates (China) and increasing urban sprawl (the Netherlands). Whatever the
reason for the increasing interest in land-use efficiency, there is relatively little knowledge on
how to measure, analyse and compare it. In regional science and economic geography most of
the research on spatial efficiency focuses on the location and land-use patterns of economic
activities, rather than on the amount of land that is actually used, or as Bapat writes, ‘the
maximization of spatial activity’ (Bapat, 2006: 128). Only the efficiency of agricultural land-
use or the productivity of rural land is analysed regularly.

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)
per unit of land. In contrast to the classical economists we omit agricultural land and analyse only industrial and commercial land which is not mixed with other land-use types. For this purpose we use data on industrial estates in the Netherlands.

Our research into industrial land in the Netherlands is also embedded in recent planning debates on industrial estates in the Netherlands. The dissatisfaction with the spatial outcome of the public planning and development of industrial land is shared by environmental pressure groups and various government agencies (VROMraad, 2006; Segeren et al., 2005). The assumption is that spatial productivity on industrial estates is low and that this is a direct result of the common strategy by municipalities to supply generous amounts of low-priced industrial land in order to promote local economic development (Needham and Louw, 2006; Louw and Bontekoning, 2007; Van der Krabben and Buitelaar, 2007). The land is then ‘spoilt’ as it cannot be used anymore for other purposes. This practice also leads to negative external effects, such as landscape pollution (Hamers and Nabielek, 2006) and the increased physical obsolescence of existing industrial estates (Janssen-Jansen, et al., 2008). It is assumed that a reduction in the development of industrial estates will increase spatial productivity. So far, however, no empirical evidence has been produced to demonstrate a relationship between the supply of industrial land and spatial productivity in the Netherlands.

In an international context we are aware only of a study by Zhu et al. (2002) in Singapore, who linked the increase in spatial productivity on industrial estates to the economic policy to develop new distriparks (which facilitated the restructuring of the Singapore manufacturing industry and altered the internal structure of firms in their utilisation of space).

In this paper we present data on regional differences in the spatial productivity of industrial land and we relate spatial productivity to local spatial planning strategies (municipal policies on industrial land development). Does a generous supply of land reduce spatial productivity? We measure the land-use efficiency of industrial land in terms of spatial productivity and analyse regional differences in spatial productivity. In section two we describe how we
calculate spatial productivity. In section three we present our calculated dataset and analyse it with regression analysis. We conclude with a discussion of our research results and the usefulness of the concept of spatial productivity.

The calculation of land productivity: methodology

Land – or spatial – productivity is defined here as the monetary added value per unit of industrial land (usually one net hectare). Industrial land is defined as land that is used exclusively for economic activities. To calculate productivity of industrial land it is necessary to separate the added value created on industrial land from the added value created on ‘other’ land. We dealt with this by looking at the relative level of employment on industrial land.

Our method to calculate land productivity consisted of four steps (see also Figure 1):

1. Determine the added value (GDP) per region (40 NUTS-3 regions) and per sector (24 sectors);
2. Determine the location of the employment (industrial estate or elsewhere);
3. Allocate the added value per sector and region to industrial estates;
4. Determine the land productivity for industrial estates.

(Figure 1 around here)

The added value in a given sector was allocated to the industrial estates in a given region \((AVI_{prs})\) as:

\[
AVI_{prs} = E_{prs} \times AV_{prs}
\]  

and to other land \((AVO_{prs})\) as:

\[
AVO_{prs} = (1 - E_{prs}) \times AV_{prs}
\]
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:

\[
AVI_{pr} = \sum_{s=1}^{S} AVI_{prs}
\]

(3)

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

\[
AVO_{pr} = \sum_{s=1}^{S} AVO_{prs}
\]

(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:

\[
LP_{pr} = \frac{AVI_{pr}}{S_{pr}}
\]

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

Three important points should be noted concerning the interpretation of the results:

1. In our calculation we used the average output per job and not the output over a year’s working time, as is common in calculations for labour productivity. The advantage of this approach was that the self-employed (for whom there are no data on working times) could be included in the calculations. One disadvantage was, however, that we had to assume that part-time jobs were equally distributed across industrial estates and beyond.

2. In our calculations we implicitly assumed that the labour productivity in each sector on industrial estates was similar to the labour productivity in the same sector outside industrial estates. We are not aware of research that assumes otherwise. This also
meant that we could not include the heterogeneity of labour in our analysis: we could not know if and how the characteristics of the labour force on industrial estates were different from other locations. The same was true for capital (or technology) inputs. There were no data available that distinguished between labour or capital inputs on industrial estates and other locations. That said, one should remember that the regional differences for these inputs at sector level were implicitly included in our calculation (or estimation) of land productivity.

3. In 2001 the calculations for the national accounts were revised. This influenced the added value for the service sectors in particular.

One obvious alternative indicator of spatial productivity is land rents. But one of the problems with this indicator is the shortage of data on prices paid. Secondly, as very little land has been traded recently (compared to the total stock), there are no prices to adequately cover all the land in our analysis. The latter aspect is tied in with the sunk costs of property (including land) investments and the fact that most firms in the Netherlands own their property (Stec Groep, 2005). However, there are also theoretical objections to the use of land rents in the analysis. First of all, rents can only be used as an alternative indicator if land markets are perfect and efficient. In reality, this is hardly ever the case and certainly not in the Netherlands where municipalities have almost a monopoly on the land market and where land values are determined by both political and economic policy considerations. As a consequence, land prices barely reflect the value of land as a production factor (Segeren, et al., 2005; Rebelo, 2009). Or, as Evans (2004:67) puts it: ‘The property market is inherently imperfect, so the market only determines a range within which the actual sale price will lie’. Secondly, there is evidence of very low elasticity in the price of industrial land in the Netherlands (Zuidema, 2004), which is partly explained by the fact that investments in land
only account for approximately 1% of business investments (Louw, et al., 2009). This also
puts the question of endogeneity into perspective.

The productivity of industrial land in the Netherlands

Despite mounting concern about their impact on the national landscape, industrial estates occupy only a small part of the total surface of the Netherlands. In 2003 they accounted for 2.3%, but this figure has risen rapidly, from only 2.0% in 1995. Employment on industrial estates increased between 1995 and 1999 from 29.1% to 31.9%. In 2003 it fell to 31.7%, a modest decrease, possibly explainable by the economic recession. A similar trend is discernible in the percentage of added value produced on industrial estates, which is slightly higher than the percentage of employment (also Table 1). The net and gross spatial productivity of industrial estates have both increased over the years. These figures show beyond doubt that industrial estates are important to the Dutch economy.

(Table 1 around here)

The rest of the paper is devoted entirely to an analysis of the net spatial productivity, because the net area is the amount of land that is designated as industrial land. Figure 2 shows the regional differences in the productivity of industrial land. In 2003 s-Gravenhage (The Hague) with €8.9 million per hectare, topped the list for spatial productivity while Oost Groningen (East Groningen) came bottom with €0.8 million. Although land productivity has increased over the years in most regions, the order from top-to-bottom has remained almost unchanged (see Figure 2), thus indicating stable regional patterns. Figure 3 shows a map of the regional
differences in net spatial productivity in 2003, which clearly indicates that the highest spatial productivity occurs in the most urbanised regions in the western part of the Netherlands (the Randstad). The Rotterdam region (Groot Rijnmond) appears to be the exception to this general picture, with a spatial productivity of €2.0 million per hectare, which is modest compared with other regions in the Randstad (see also Figure 2). The map in Figure 3 also shows that the regions with the lowest spatial productivity lie in the peripheral regions of the Netherlands, with the regions in between showing modest spatial productivity.

(Figure 2 around here)

(Figure 3 around here)

How can we explain the regional differences in spatial productivity on industrial estates? We drew a distinction between variables relating to spatial planning strategies (our main objective) and two general variables which we used as control variables. The first of the policy-related variables was the supply of industrial land. Needham and Louw (2006) suggest that a high supply of industrial land in the Netherlands results in low spatial productivity. In regions with a high demand for land and low levels of supply one would expect the price of industrial land, and hence, the land productivity to be high. Unfortunately, we were not able to test this relationship empirically, because of the absence of reliable data on the prices of serviced industrial land on industrial estates. The only price data in IBIS, the national database on industrial estates, are the ‘asking prices’ set by the suppliers which, in most cases, probably exceed the selling prices (the prices companies actually pay for their land). However, we could still measure the scarcity of land by calculating regional differences in the supply-demand ratio. We defined supply as the area of building land on industrial estates that was immediately available to companies in a particular year. The demand was the
accumulated area of land on industrial estates that was issued to companies up to that same year. Because Needham and Louw (2006) assume that past policies influence current land-use, we used a supply-demand ratio from the past (1988) and the three years for which we calculated the spatial productivity (1995, 1999 and 2003).

The second policy-related variable was the percentage of jobs in a region located on industrial estates. A high percentage of jobs on industrial estates in a region would indicate that in the past there had been (and probably still was) a spatial policy that favoured the development of industrial estates. If the assumption in the introduction is right, a negative relationship should exist between the percentage of employment on industrial estates and spatial productivity.

The third policy-related variable was the presence of physically obsolete industrial estates. In Dutch policy debates it is argued that due to the development of many new industrial estates, companies find it more efficient to relocate than to invest in their current properties. This implies that older estates are characterised by low employment densities due to many vacant premises and the presence of marginal operating companies which cannot afford to relocate. It was therefore expected that a region with a high share of obsolete industrial land would have a low level of spatial productivity. These data were only available for 2003.

Besides these policy-related variables there were other variables that we wanted to control for. Louw and Bontekoning (2007) suggest that regional variations in sector composition on industrial estates could be an explanation. Different branches of industry require different amounts of land. Service sector companies, for example, require only a limited amount of space for each job and are accommodated in multi-storey office buildings, whereas manufacturing companies use single-storey buildings. Some manufacturing sectors such as refineries, chemical plants and transport require large areas of land. The variations in sector composition on industrial estates should therefore influence employment densities which should, in turn, influence spatial productivity. A high share of service sector employment was
expected to increase spatial productivity, whereas a high share of manufacturing sector employment was expected to decrease spatial productivity. Because these variables were significantly correlated we only applied the share of manufacturing employment.

A second plausible explanation for the regional differences was the difference in regional employment densities. Ciccone and Hall (1996) showed that, due to agglomeration effects, an increase in employment densities has a positive effect on the average labour productivity. Intriguing in this respect is that regional differences in labour productivity in the Netherlands (see Broersma and Van Dijk, 2005) are relatively small compared with regional differences in land productivity. This suggests that regional differences in labour productivity as such have no significant influence on land productivity, and that differences in land use are therefore more important. Since industrial estates are part of the regional economy and cannot be seen as isolated sites, we applied the regional urbanisation rate (average number of addresses per sq kilometre in a region) instead of the employment densities on industrial estates (1).

Other variables such as proximity to markets or a general measure of access were not included because of the limited number of regions we could use in our analysis (see below). Moreover, we did not compare the spatial productivity of individual estates, but we did compare the average spatial productivity of estates by region. It was likely that access to markets would have an influence mainly at the level of individual estates in relation to local markets, rather than in relation to regional or national markets.

(Table 2 around here).

Table 2 provides descriptive statistics for the variables we used in our analysis. The fact that the mean, range and standard deviation are much higher for the supply-demand ratio for 1988 than for the supply-demand ratios for 1995, 1999 and 2003 stems from differences in the IBIS...
database. In 1988 only estates with a minimum size of five hectares were included in the database. In the other years the minimum size was one hectare. This has scarcely any influence on the size of the supply as most of the industrial land supply is on estates larger than five hectares. However, the accumulated amount of land issued to companies in 1995 was 2.6 times higher than in 1988. So the mean, range and standard deviation for 1988 are higher than for the other three years. The IBIS database for 1988 reflects its original purpose, namely, to monitor the supply of industrial land, whereas in the 1990s the purpose was to monitor the stock of industrial land.

To find empirical evidence for the relationship between net land productivity and the independent variables described above, we estimated ordinary least squares (OLS) models for 1995, 1999 and 2003. We analysed only net land productivity because this was the amount of land used by firms. Multi-collinearity was checked by analysing correlations between the independent variables. In 1995 and 1999 a significant correlation was found at the 1% level between the urbanisation rate and the share of manufacturing employment. In 2003 a significant correlation was found between these variables at the 5% level. The same levels of significance applied for the correlation between the supply-demand ratios for 1988 and 1995/1999 and 2003. In the 2003 dataset a significant correlation at the 1% level was found between the supply-demand ratio for 2003 and the share of obsolete estates. These variables were, however, included in the analyses because the variance inflation factor (VIF) for these variables in all of the models was below 2.5. According to Field (2000) multi-collinearity becomes a problem if VIF > 10.

There is also the issue of spatial autocorrelation. Although this is highly relevant in regional science when regional differences are analysed in the form of an OLS model, we argue that it was not appropriate to include spatial autocorrelation in our analysis. The reason for this is that we were not dealing with continuous space but with many discontinuous spaces in the
form of industrial estates within a region. These approximately 3,500 estates accounted for only 2.3% (2003) of the total surface area of the Netherlands and were scattered all around the country in both urban and rural areas. Spatial concepts such as distance-decay, spatial interaction, and spatial randomness, which form the theoretical foundation of spatial autocorrelation and which assume continuous space, did not apply to our data. On these theoretical grounds the inclusion of spatial autocorrelation could be justified only if the analysis was executed on the scale of individual industrial estates. Our aggregated data were not, however, suitable for calculating land productivity on this spatial scale. Moreover, given the relatively small size of individual industrial estates, it would be unrealistic to assume that they would have a significant influence on other estates in the region, let alone on estates in a neighbouring region (2).

Because we were primarily interested in the relative importance of the independent variables and the direction of the associations, only standardised parameters are presented here (Tables 3, 4 and 5). In all of the models the control variables have the expected signs. Regional urbanisation rates are positively related to spatial productivity and the level of manufacturing employment is negatively related to spatial productivity. Also, both control variables are highly significant. Only the share of manufacturing in the 2003 models is significant at the 5% level instead of the 1% level in the 1995 and 1999 models. This slight drop in significance is probably tied in with the general decline in the level of manufacturing employment on industrial estates (see Table 2). It is clear from the standardised betas that in all of the models the urbanisation rate has the largest effect on the spatial productivity of the two control variables. This finding is consistent with the findings of Ciccone and Hall (1996), Ciccone (2002) and more general knowledge about urban economics: high densities go hand-in-hand with intensified land use.

Among the policy variables only the supply-demand ratio for 1988 is significant and has the expected sign in all of the models for every year (Equations 1 in Tables 3, 4 and 5). That
means that a high supply-demand ratio in 1988 led to lower spatial productivity in 1995, 1999 and 2003. The supply-demand ratios for 1995, 1999 and 2003 (Equations 2 in Tables 3, 4 and 5) have a less uniform effect on spatial productivity. Only in the 1995 and 1999 models does this variable show the expected negative sign and then it is only significant in 1999. In the 2003 model the supply-demand ratio is positively related to spatial productivity but is not significant (Equation 2 in Table 5). These findings imply that past supply-demand ratios have more effect on spatial productivity than recent supply-demand ratios. This may be due to the high level of supply-demand ratios in 1988 compared with 1995, 1999 and 2003 (see Table 2), which is mainly due to differences in the IBIS database.

(Tables 3-5 around here)

The share of regional employment on industrial estates is, as expected, negatively related to spatial productivity (Equations 3 in Tables 3, 4 and 5). This effect is not significant, as shown in Equation 3 models of Tables 3, 4 and 5. However, in the overall model for 1999 (Equation 4 in Table 4) the share of employment on industrial estates is significant while both supply-demand ratios are not.

In the 2003 model the share of obsolete industrial land does not, as expected, have a negative effect on spatial productivity. The correlations between this variable and the urbanisation rate and supply-demand ratios for 1988 and 2003, which are negative, seem to suggest a relationship other than was expected. A large number of physically obsolete industrial estates does not necessarily imply low spatial productivity at regional level. The above-mentioned rationale behind the expected negative sign may not even be valid since there is a significant positive correlation between the share of obsolete industrial land and the urbanisation rate and a significant negative correlation with supply-demand ratios for both 1988 and 2003,
suggesting that the degree of obsolescence may have been caused by an under-supply rather than an over-supply.

By comparing the regression coefficients in the various models we can see how ‘stable’ the influence of that variable is over time. This is particularly relevant for the supply-demand ratio for 1988 given that it is insignificant in the overall model for 1999 (Equation 4), but significant in the 1995 and 2003 models. We compared the non-standardised coefficients in the models with each other – thus checking for stability over time – using the Confidence Interval for Difference (Cohen et al., 2003: 46-47). We applied this technique to models containing four variables: both control variables, the supply-demand ratio 1988 and the share of employment on industrial estates. The analysis revealed no significant difference between the regression coefficients of these variables between the 1995, 1999 and 2003 models.

Accordingly, our analysis of the regional differences in spatial productivity on industrial estates provides empirical evidence for the hypothesised relationship between the historical supply-demand ratio and spatial productivity. This is confirmed by Equation 4 in Table 3 and Equation 5 in Table 5. Using all policy variables simultaneously results in significant estimates for this policy variable in 1995 and 2003. In the 1999 model only the share of employment on industrial estates was significant, but the analyses with the Confidence Interval for Difference between the regression coefficient indicated that the coefficients themselves showed no significant difference between the models. Both control variables have a significant effect on spatial productivity. Taking the magnitude of the standardised coefficients of these variables into consideration, their effect on the spatial productivity is greater than the supply-demand ratio.
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
externalities on the scale of industrial estates. Agglomeration effects most probably exceed this local geographical scale.

In policy terms, the concept of spatial productivity is relevant to debates about the efficient use of scarce land. Information on (regional differences in) industrial land productivity can be particularly valuable in countries and regions where there is strong pressure to develop available land. The regression analysis in this paper shows that differences in land productivity can be partly explained by policy-related variables, which suggests that the level of spatial productivity of industrial land in a given region can be influenced.

The usefulness of the concept of spatial productivity must be considered theoretically as well as in policy terms. By using spatial productivity we treated land as if it were an independent production factor like labour. As in the calculations for labour productivity, we allocate all the added value to one production factor, in our case, land. However, the trend in economics over the last century has been to combine land with capital, effectively condensing the production factors to only labour and capital. The underlying logic for this practice is that land does not actually participate in industrial production, as it does in agriculture. Land is a necessity for industrial production but, contrary to other production factors, it is not worn out or transformed in the process.

As a production factor land has two attributes: location and the size of the production site (Alonso, 1964). According to Hubacek and Vazques (2002), producers usually take proportionate decisions between land and other factor inputs, when deciding on long-term investments. In the short term producers cannot substitute land for other factor inputs, because land is a quasi-fixed factor of production. Therefore, in the short-term resource allocation takes place on land, without considering land as a factor in the production process itself. By measuring spatial productivity we determine how much added value is created by different decisions on resource allocation (including capital, labour, knowledge and location) on a
particular amount of land. Therefore, land use in manufacturing and services is not a production factor in the strict sense of an input, as in agriculture. However, land, in terms of land use, is a necessary condition for production. Analysing spatial productivity therefore helps to improve our knowledge of the allocation process of production factors on land and the efficiency of this process and thus contributes to discussions about sustainable land use.
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.

Acknowledgements

The authors wish to acknowledge the assistance of the Dutch Government through the Habiforum Innovative Land Use Programme. We also wish to thank two anonymous referees and Barrie Needham for their comments on earlier versions of this paper. The usual disclaimer applies.
References


Figure 1 Four steps to calculate land productivity

1. Added value by sector and region
2. Location of employment by sector and by region
3. Total added value on industrial estates in a region
4. Total area of industrial estates in regions
5. Land productivity on industrial estates in regions
Table 1  Some descriptive statistics on Dutch industrial estates.

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

* 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.

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>range</th>
<th>standard deviation</th>
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<tr>
<td><strong>1995</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Net spatial productivity</td>
<td>1.99</td>
<td>4.07</td>
<td>1.02</td>
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<tr>
<td>Share manufacturing jobs</td>
<td>42.29</td>
<td>54.59</td>
<td>12.54</td>
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<tr>
<td>Urbanisation rate</td>
<td>1374.93</td>
<td>4028.00</td>
<td>848.51</td>
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<tr>
<td>Share of jobs on industrial estates</td>
<td>31.14</td>
<td>28.35</td>
<td>6.81</td>
</tr>
<tr>
<td>Supply-demand ratio 1988</td>
<td>41.37</td>
<td>149.89</td>
<td>26.95</td>
</tr>
<tr>
<td>Supply-demand ratio 1995</td>
<td>15.04</td>
<td>51.24</td>
<td>12.10</td>
</tr>
<tr>
<td><strong>1999</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net spatial productivity</td>
<td>2.20</td>
<td>5.91</td>
<td>1.23</td>
</tr>
<tr>
<td>Share manufacturing jobs</td>
<td>37.85</td>
<td>41.17</td>
<td>10.91</td>
</tr>
<tr>
<td>Urbanisation rate</td>
<td>1394.45</td>
<td>4107.00</td>
<td>865.96</td>
</tr>
<tr>
<td>Share of jobs on industrial estates</td>
<td>32.93</td>
<td>26.93</td>
<td>6.76</td>
</tr>
<tr>
<td>Supply-demand ratio 1988</td>
<td>41.37</td>
<td>149.89</td>
<td>26.95</td>
</tr>
<tr>
<td>Supply-demand ratio 1999</td>
<td>10.38</td>
<td>44.30</td>
<td>9.80</td>
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<tr>
<td><strong>2003</strong></td>
<td></td>
<td></td>
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<tr>
<td>Net spatial productivity</td>
<td>2.53</td>
<td>8.10</td>
<td>1.51</td>
</tr>
<tr>
<td>Share manufacturing jobs</td>
<td>34.26</td>
<td>41.98</td>
<td>10.70</td>
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<tr>
<td>Urbanisation rate</td>
<td>1359.18</td>
<td>3336.00</td>
<td>708.57</td>
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<td>Share of jobs on industrial estates</td>
<td>32.86</td>
<td>25.52</td>
<td>6.26</td>
</tr>
<tr>
<td>Supply-demand ratio 1988</td>
<td>41.37</td>
<td>149.89</td>
<td>26.95</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>Share of obsolete estates</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------</td>
<td>---------------------------</td>
<td></td>
</tr>
<tr>
<td>Supply-demand ratio</td>
<td>10.96</td>
<td>32.99</td>
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<tr>
<td></td>
<td>41.61</td>
<td>77.27</td>
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<tr>
<td></td>
<td>9.99</td>
<td>17.84</td>
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</table>
Figure 2    Net land productivity on industrial estates per region in 1995, 1999 and 2003
(x € mln / ha).
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).

<table>
<thead>
<tr>
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<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urbanisation rate</td>
<td>0.50***</td>
<td>0.48**</td>
<td>0.48***</td>
<td>0.48***</td>
</tr>
<tr>
<td></td>
<td>(4.21)</td>
<td>(3.85)</td>
<td>(3.63)</td>
<td>(4.01)</td>
</tr>
<tr>
<td>Share manufacturing employment</td>
<td>-0.36***</td>
<td>-0.34**</td>
<td>-0.29***</td>
<td>-0.37***</td>
</tr>
<tr>
<td></td>
<td>(-3.05)</td>
<td>(-2.64)</td>
<td>(-3.03)</td>
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<tr>
<td>Supply-demand ratio 1988</td>
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<td></td>
<td></td>
<td>-0.35**</td>
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<tr>
<td></td>
<td>(-2.80)</td>
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<tr>
<td>Supply-demand ratio 1995</td>
<td></td>
<td>-0.16</td>
<td>0.07</td>
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<tr>
<td></td>
<td></td>
<td>(-1.54)</td>
<td>(0.52)</td>
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</tr>
<tr>
<td>Share employment on estates</td>
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<td>-0.12</td>
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<tr>
<td></td>
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<td>(-0.40)</td>
<td>(-1.24)</td>
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<tr>
<td>F</td>
<td>26.37***</td>
<td>21.60***</td>
<td>19.64***</td>
<td>16.18***</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.66</td>
<td>0.61</td>
<td>0.59</td>
<td>0.66</td>
</tr>
</tbody>
</table>

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).

<table>
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<th>(1)</th>
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<th>(3)</th>
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</thead>
<tbody>
<tr>
<td>Urbanisation rate</td>
<td>0.48***</td>
<td>0.42***</td>
<td>0.43***</td>
<td>0.40***</td>
</tr>
<tr>
<td></td>
<td>(4.07)</td>
<td>(3.49)</td>
<td>(3.19)</td>
<td>(3.39)</td>
</tr>
<tr>
<td>Share manufacturing employment</td>
<td>-0.39***</td>
<td>-0.43***</td>
<td>-0.43***</td>
<td>-0.40***</td>
</tr>
<tr>
<td></td>
<td>(-3.35)</td>
<td>(-3.57)</td>
<td>(-3.25)</td>
<td>(-3.52)</td>
</tr>
<tr>
<td>Supply-demand ratio 1988</td>
<td>-0.27***</td>
<td></td>
<td>-0.24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-3.21)</td>
<td></td>
<td>(-2.01)</td>
<td></td>
</tr>
<tr>
<td>Supply-demand ratio 1999</td>
<td>-0.24***</td>
<td></td>
<td>-0.11</td>
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</tr>
<tr>
<td></td>
<td>(-2.74)</td>
<td></td>
<td>(-0.95)</td>
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<tr>
<td>Share employment on estates</td>
<td>-0.11</td>
<td>-0.020**</td>
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<td></td>
<td>(-1.14)</td>
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<td>31.85***</td>
<td>25.59***</td>
<td>24.25***</td>
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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).

<table>
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<th>(5)</th>
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<tr>
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<td>0.65***</td>
<td>0.62***</td>
<td>0.55***</td>
<td>0.58***</td>
</tr>
<tr>
<td></td>
<td>(5.39)</td>
<td>(5.13)</td>
<td>(5.14)</td>
<td>(4.11)</td>
<td>(4.69)</td>
</tr>
<tr>
<td>Share manufacturing employment</td>
<td>-0.28**</td>
<td>-0.28**</td>
<td>-0.27**</td>
<td>-0.34**</td>
<td>-0.29**</td>
</tr>
<tr>
<td></td>
<td>(-2.53)</td>
<td>(-2.26)</td>
<td>(-2.21)</td>
<td>(-2.65)</td>
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</tr>
<tr>
<td>Supply-demand ratio 1988</td>
<td>-0.20**</td>
<td></td>
<td></td>
<td></td>
<td>-0.26***</td>
</tr>
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<td></td>
<td>(-2.44)</td>
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<td>(-2.91)</td>
</tr>
<tr>
<td>Supply-demand ratio 2003</td>
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<td>0.04</td>
<td></td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.44)</td>
<td></td>
<td>(1.69)</td>
<td></td>
</tr>
<tr>
<td>Share employment on estates</td>
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<td>-0.12</td>
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</tr>
<tr>
<td></td>
<td>(-0.89)</td>
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<td>(-1.48)</td>
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<td></td>
</tr>
<tr>
<td>Share obsolete</td>
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<td>0.10</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.21)</td>
<td>(0.97)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
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<td>31.15***</td>
<td>31.86***</td>
<td>32.67***</td>
<td>21.47***</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.74</td>
<td>0.70</td>
<td>0.70</td>
<td>0.71</td>
<td>0.76</td>
</tr>
</tbody>
</table>

T-values in parentheses.

*** significant at the 1% level.

** significant at the 5% level.