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## Non-linearity of location factors

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## **Non-linearity of location factors**

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### **Abstract**

In this paper, the widespread assumption of linear relations between location factors and location advantage for firms is questioned. Analysis is made for larger municipalities and for districts in Switzerland. Significance levels of a linear regression model are compared to models where location factors are transformed in a non-linear way. Results suggest various non-linearities. For instance, a critical mass effect can be observed for available business zones and for personal income taxes. The latter would suggest that some firms are more sensitive to personal income taxes as a location factor than others. The more sensitive ones will avoid regions with personal income taxes above average, making this location factor less relevant in avoided regions. For other location factors the opposite carries and a critical mass effect was found for corporate taxes and human capital, suggesting that an improvement of an already high level adds less than starting from lower levels. Accessibility by public transport is associated with both a critical mass effect and a saturation effect which means that accessibility should neither be a bottleneck nor luxurious. Results like these may have direct implications for location factor policy.

### **Keywords**

firm location, location factors

### **JEL-Codes**

H32, R11, R30

### **Citations**

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## 1. Introduction

What location factors matter most? This is a classic question asked in the branch of regional economics that seeks to explain regional growth divergences (Capello, 2007). In this paper, we examine the fact, that most location factor models assume linear models with independent location factors. We explore which of the common location factors reaches a higher explanatory power if we allow for non-linear relations between location factors and locational advantage.

At first sight, it should not be a very difficult task to deliver empirical proof of the most relevant location factor for businesses at least for a certain region. One may also expect a possibility to find a robust order in the relevance of different location factors. Looking at such rankings made for Switzerland, for example, there are academic sources available (Vettiger 1994, Rietveld und Bruinsma 1998, Hilber 1999, Bürgle 2006, Berlemann/Tilgner 2007, Hu et al. 2008) as well as publications of banks or consultants, (BAK 1998, Credit Suisse Economic Research 2006, Ecoplan und Büro Widmer 2004, WEF 2009).

A comparison of such studies shows, that rankings are not robust. For example, accessibility is the most important location factor for Hilber (1999), while the study of Ecoplan und Büro Widmer (2004) finds accessibility on the seventh rank. The overview of Bodenmann and Axhausen (2010) shows how this is similar for tax burden, availability of human capital and other location factors.

While policy makers wish some more directive results, there are a number of methodological reasons why robustness for such location factors is not achievable without further ado (Berlemann/Tilgner 2006 or Bodenmann/Axhausen 2010):

1. Denotations of location factors vary slightly among studies. Definitions behind these denotations may differ even more. The same denotation 'accessibility' may stand for fundamentally different concepts, for example, if giving different weight to different modes of transportation from foot to air transport. Since authors of studies are to a large extent free to define location factors, studies will not show robust results on factor rankings even if location factors seem similar.
2. Methods can vary fundamentally or in detail. Location factor rankings may base on surveys or on secondary data. Even if location factors would be defined the

same way and surveys would be made throughout, survey techniques and questions can still differ from each other, leading to different results.

3. Location factor studies cannot avoid choosing a certain area where empirical data is collected. This choice biases location rankings that build on enterprise surveys. As long as it is assumed that enterprises choose their location depending on location factors, they will stress the importance of the factors actually given. For example, in a tax heaven region, more enterprises will value a low tax burden to be relevant as compared to an average taxed region (Bodenmann and Axhausen, 2010). More and other preconditions like the evolution of industries in a region would lead to individual factor location rankings for each region, even if other difficulties could be controlled.
4. A very similar argument holds for the period when empirical data is collected. Economic cycles or technical progress may influence the importance of location factors.
5. Different industries prefer different location factors (Bürgle 2006). If there is a general location factor ranking, industries must be weighted in a certain way in order to reach this.
6. Factors are likely to be interdependent with each other and they should be transformed into group functions (Hu et al. 2008).
7. Finally, location factors are often considered to have a linear influence on location choice. This may not be suitable in many ways.

This paper investigates the last point further leaving aside points 1 through 6. Still, all other points should be borne in mind when comparing location factor rankings.

## **2. Linearity or other shapes?**

Location factors can be understood as a set of indicators of the locational advantage of a certain region. Most studies presume a linearly increasing relationship between locational advantage and respective location factors (see Figure 1).

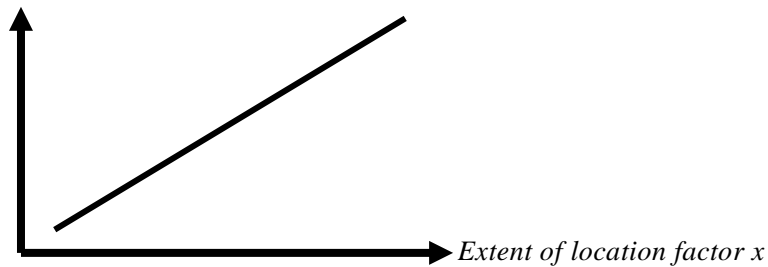
*Locational advantage*

Figure 1: Schematic illustration of linear relationship between locational advantage and location factors

This linearity assumption models reality in a number of cases well enough to receive useful results. However, there are cases in which this is a far reaching simplification. A practical example can illustrate such a situation: Whether a four lane highway ought to be enlarged to a six lane highway depends on usual traffic. If this highway is congested frequently, enlargement adds to the locational advantage. If, however, traffic on the highway is at all times only light, any enlargement has no influence on locational advantage. Such a *saturation* effect may in principle exist for any location factor. For example, Echebarria and Barrutia (2011) find that the relationship between social capital and innovation is not linear but social capital reaches a saturation level and may even turn into negative, resulting in an inverted U-shaped relationship. Other shapes may be possible in other instances. If a certain location factor needs to reach a certain *critical mass* in order to become effective and reaches a saturation point later, we would find an S-shaped relationship as shown in Figure 2.

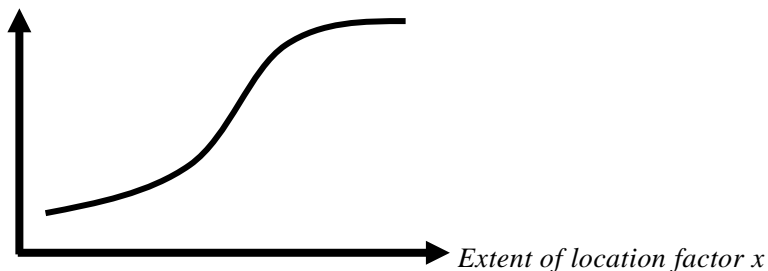
*Locational advantage*

Figure 2: Schematic illustration of an S-shaped relationship between locational advantage and location factors

In the following, we set up a simple model for locational advantage in Switzerland with some commonly used location factors and look for factors that explain locational advantage better if linearity is replaced with another shape, including critical mass and saturation effects.

### 3. The model

First, we build a regression model that seeks to explain locational advantage for Swiss municipalities and districts respectively. The model builds on secondary data from years between 2006 and 2009 that can be obtained from official statistical offices. Since many tax data are only available for municipalities with more than 2,000 inhabitants, municipalities with less inhabitants are omitted, leaving  $n = 813$  municipalities.

#### 3.1. Municipalities or regions?

What is the ideal size of a region to be analysed? Availability of data for the Swiss Cantons would be excellent; however, there are only 26 simultaneous observations possible, too little to trace our question. Municipalities offer more simultaneous observations, however, quality and availability of data decreases and there is the danger that spill over effects prevail and distort estimates (Berlemann/Tilgner 2007, p. 15). Still, a large number of observations is beneficial for our search of non-linearities; hence, we chose these comparably small areas and limit the location factors to where we find useful data. In order to control for distortions due to spill overs, we aggregate municipal data to the next larger administrative division, the districts, and build a parallel model for these regions, where we still have  $n = 151$  in Switzerland.

#### 3.2. Indicators for locational advantages as the explained parameter

Locational advantage cannot be observed directly, it is more of an abstract concept. Hence we need an indicator for locational advantage, and some prudence is necessary for this as well.

- Many possible indicators such as local GDP, number of jobs and others relate more to the sheer *size* of a region rather than to its locational advantage.
- If indicators are adapted to the regions size like local GDP per capita or number of jobs per square kilometre, they relate more to *density* within a region rather than to its locational advantage. Of course, size or density may be location factors by themselves, however, in a regression model we might end up with a model that explains size with size indicators or density with density indicators – and all this with excellent t-statistics, as we suspect for the model of Berlemann/Tilgner (2007), for example.

- *Growth* indicators such as growth of GDP or of number of jobs in per cent per year can reflect only changes in a certain time period. However, locational advantages often evolve over long periods of time. Historically long standing locational advantages are out of relative growth measures, but would still be of our interest (Capello 2007, p. 6).

Should locational advantage be mirrored by size, density or growth? There is no easy way out of this trilemma. We opt for local GDP divided by the area that is zoned for business. We need to keep in mind that this also indicates density as such, therefore, location factors should *not* refer to density as well, such as inhabitants per square kilometre or similar.

Since statistics on local GDP is not available for individual Swiss municipalities, we estimate this measure by using job statistics for different sectors in each municipality and data for average productivity in these sectors. The way we measure local GDP will ignore job productivities that are below or above average in a particular firm residing in a particular region. We assume that such performances are due to management and not directly linked to local advantage. In other words, local advantage is assumed to have an impact on number of jobs in particular industries, but not necessarily on their individual productivity. Anyway, this assumption will lose some relevance in the long run, since productive firms will presumably attract more jobs and vice versa.

If  $n$  denotes the number of regions,

$$(1) \quad \mathbf{a} = [a_1 \dots a_n]$$

is the vector containing the indicators for locational advantages.

### 3.3. Location factors as explaining parameters

Krugman (1991) finds that transportation costs, economies of scale and factor mobility may be the few parameters shaping the geographical structure of an economy. Bodenmann and Axhausen (2010) propose production factors, business environment, governmental environment and geographical environment as main determinants of companies' location choice. By using a factor analysis, Credit Suisse (2009) extracts three main locations factors: taxation, education of workforce and traffic-related accessibility.

Building the basic model, explaining parameters should be interesting for examination of our hypothesis, that some location factors perform better if they are not assumed to

have a linear influence on locational advantage. Hence, the explanatory power of the model is initially of lesser importance, since improvements in t-statistics should be visible when the model is changed. Candidates for our hypothesis shall be: tax burden (personal income tax and tax on earnings), human capital, accessibility by public transport and availability of business land.

We denote these  $m = 5$  location factors as vectors

$$(2) \quad \mathbf{s}_k = [s_{1,k} \dots s_{n,k}] \text{ with } k \in [1 \dots m]$$

and with the following attributions:

$\mathbf{s}_1$ : Personal income tax

Swiss Federal Department of Science publishes every year tax data for all Swiss municipalities. Data includes tax burden for different household types and different income segments. By giving relative weights to these different groups, tax burdens for the year of 2006 are averaged to a single tax burden value for each municipality. The municipality with the lowest tax burden is Wollerau (Canton of Schwyz) and the municipality with the highest tax burden is Couvet (Canton of Neuchâtel).

$\mathbf{s}_2$ : Corporate Tax

Taxes paid by incorporated firms are calculated as proposed by Morscher, Rohrer and Schwenter (2011). Based on balance sheets and income statements of 4,015 firms, the average capital of CHF 1,350,000 and the average earning of CHF 400,000 were taxed in all municipalities. The sum of all taxes in each municipality was added and finally transformed a linear way delivering highest values for all municipalities of the Canton of Obwalden and the lowest values for some equally expensive municipalities in the Canton of Basel-Landschaft.

$\mathbf{s}_3$ : Human Capital

To measure human capital on a municipality level, three possibilities were considered. One is data from the Federal Population Census as used by Credit Suisse (2006), for example. However, this dataset is available for the year 2000 only which we consider too far from the point in time to be explained. The two others are data from the Swiss



Graduate Survey which provides panel data for university graduates one and five years after graduation (Bundesamt für Statistik, 2009). The latter dataset is available for the year 2007 (graduates of 2002) and was preferred to the other because it is assumed that occupation after five years is more stable than one year after graduation. It should be noted that this dataset shows only the geographic choice of one cohort of graduates, but correlations with the two other alternatives is high.

**s<sub>4</sub>:** Building zones with public transport

This data is derived from official data from the Swiss Federal Office for Spatial Development. For every municipality, business and industrial building zones are multiplied by weight factors reflecting the quality of public transport access and then added together. The quality of public transport access is influenced by the proximity of the next public transport stop, by the frequency of stops and by the number of directions and transport modes.

**s<sub>5</sub>:** Accessibility with public transport

While the previous indicator focuses on land use and accessibility within a municipality, the actual accessibility indicator measures the job potential that can be reached from a certain municipality by using public transport. This indicator is a weighted sum of accessible workplaces, while those being close and easier to reach are weighted higher than those farther from the municipality (see for example Aberegg and Tschopp 2010). Accessibility by private transport added too little explanation for locational advantage and was excluded from the model.

#### 4.4 Regression equation and its reformulation

In conjunction, vectors  $\mathbf{s}_k$  deliver the  $(n \times m)$  – matrix  $\mathbf{S}$  for all  $m$  location factors in all  $n$  regions. Using  $\boldsymbol{\beta}$  as vector for regression coefficients  $[\beta_1 \dots \beta_m]$  and  $\mathbf{u}$  as vector for error terms  $[u_1 \dots u_m]$ , we can formulate the regression equation (Assenmacher 2002 or Hackl 2005) as

$$(3) \quad \mathbf{a} = \mathbf{S}\boldsymbol{\beta} + \mathbf{u}$$

Calculation of this multiple regression delivers t-statistics for each location factor as an indication that the location factor effectively helps to explain locational advantage with  $k \in [1..m]$ . We denote with  $t_k$  the (one sided) likelihood that  $\mathbf{s}_k$  does not help to explain locational advantage.

So far, this is a usual regression equation. To check our hypothesis, we reformulate equation (3) and replace it with

$$(4) \quad \mathbf{a} = \mathbf{S}_k^j \boldsymbol{\beta}_k^j + \mathbf{u}_k^j$$

where

$$(5) \quad \mathbf{S}_k^j = \begin{vmatrix} s_{1,1} & \dots & s_{n,1} \\ \vdots & & \vdots \\ f^j(s_{1,k}) \dots f^j(s_{n,k}) \\ \vdots & & \vdots \\ s_{1,m} & \dots & s_{n,m} \end{vmatrix}$$

and location factor  $k$  is brought into a non-linear form by function  $f^j(\cdot)$ . For every function  $f^j(\cdot)$ , t-statistics change and  $t_k^j$  indicate the likelihood that  $f^j(\mathbf{s}_k)$  does not help to explain locational advantage. We trace interesting functions  $f^j(\mathbf{s}_k)$  by using fraction  $t_k / t_k^j$ , with high values giving an indication that application of  $f^j(\cdot)$  on  $\mathbf{s}_k$  reveals a non-linearity for location factor  $k$ . For shorter display, we use the common logarithm (to the base ten)

$$(6) \quad \delta_k^j = \lg (t_k / t_k^j)$$

For example, for the identity function  $f^0(x) = x$ ,  $\delta_k^0$  is zero. While every value of  $\delta_k^j > 0$  indicates an improvement of t-statistics, we define a critical value for  $\delta_k^j$  to have a margin of factor ten at

$$(7a) \quad \delta_k^j > 1$$

In a second and stricter version we would consider  $f^j(\mathbf{s}_k)$  a suspect deviation if

$$(7b) \quad \delta_k^j > 2 \wedge t_k > 0.01$$

Here, as a second condition, location factors *must not* be of high significance in the original regression equation (3), because this raises the danger that high values for  $\delta_k^j$  are incidental.

In the next chapter, we will first use condition (7b) and then (7a) to select functions  $f^j(\cdot)$  for modified regression models.

#### 4.5 Definition of functions for non-linearity

There is an infinite number of functions  $f^i(.)$  we could examine. For further analysis, we define ten functions  $f^1(.)$  to  $f^{10}(.)$  as follows. Ranges of location factors are divided into four quantiles, each having a range of a quarter of the total range, that is for each of the  $k$  location factors  $\frac{1}{4} (\max(s_i) - \min(s_i))$ . Function  $f^1(.)$  for example reflects a saturation effect after the first quantile:

$$(8) \quad \begin{aligned} f^1(s_{n,k}) &= s_{n,k} & | & \quad s_{n,k} < q_{1,k} \\ f^1(s_{n,k}) &= q_{1,k} & | & \quad s_{n,k} \geq q_{1,k} \end{aligned}$$

with  $q_{1,k} = \frac{1}{4} (\max(s_k) - \min(s_k)) + \min(s_k)$  and  $k \in [1..m]$

Function  $f^2(.)$  reflects a critical mass effect up to the end of the first quantile and a saturation effect after the second quantile:

$$(9) \quad \begin{aligned} f^2(s_{n,k}) &= q_{1,k} & | & \quad s_{n,k} \leq q_{1,k} \\ f^2(s_{n,k}) &= s_{n,k} & | & \quad q_{1,k} < s_{n,k} < q_{2,k} \\ f^2(s_{n,k}) &= q_{2,k} & | & \quad s_{n,k} \geq q_{2,k} \end{aligned}$$

with  $q_{1,k} = \frac{1}{4} (\max(s_k) - \min(s_k)) + \min(s_k)$   
and  $q_{2,k} = \frac{1}{2} (\max(s_k) - \min(s_k)) + \min(s_k)$  and  $k \in [1..m]$

And so on; to be shorter, functions are displayed in the following table. For reasons of symmetry,  $f^4(.) \equiv f^7(.)$ :

Saturation at <i>critical mass after</i>	<b>0</b>	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	<b>1</b>
<b>1</b>	n.a.	n.a.	n.a.	n.a.	n.a.
$\frac{3}{4}$	n.a.	n.a.	n.a.	n.a.	$f^{10}(.)$
$\frac{1}{2}$	n.a.	n.a.	n.a.	$f^9(.)$	$f^8(.)$
$\frac{1}{4}$	n.a.	n.a.	$f^2(.)$	$f^4(.) \equiv f^7(.)$	$f^6(.)$
<b>0</b>	n.a.	$f^1(.)$	$f^3(.)$	$f^5(.)$	$f^0(.)$

Table 1: Saturation and critical mass effects in our function definitions.

For more clarity, these functions are displayed graphically with  $f: A \rightarrow B$ , see table 2.

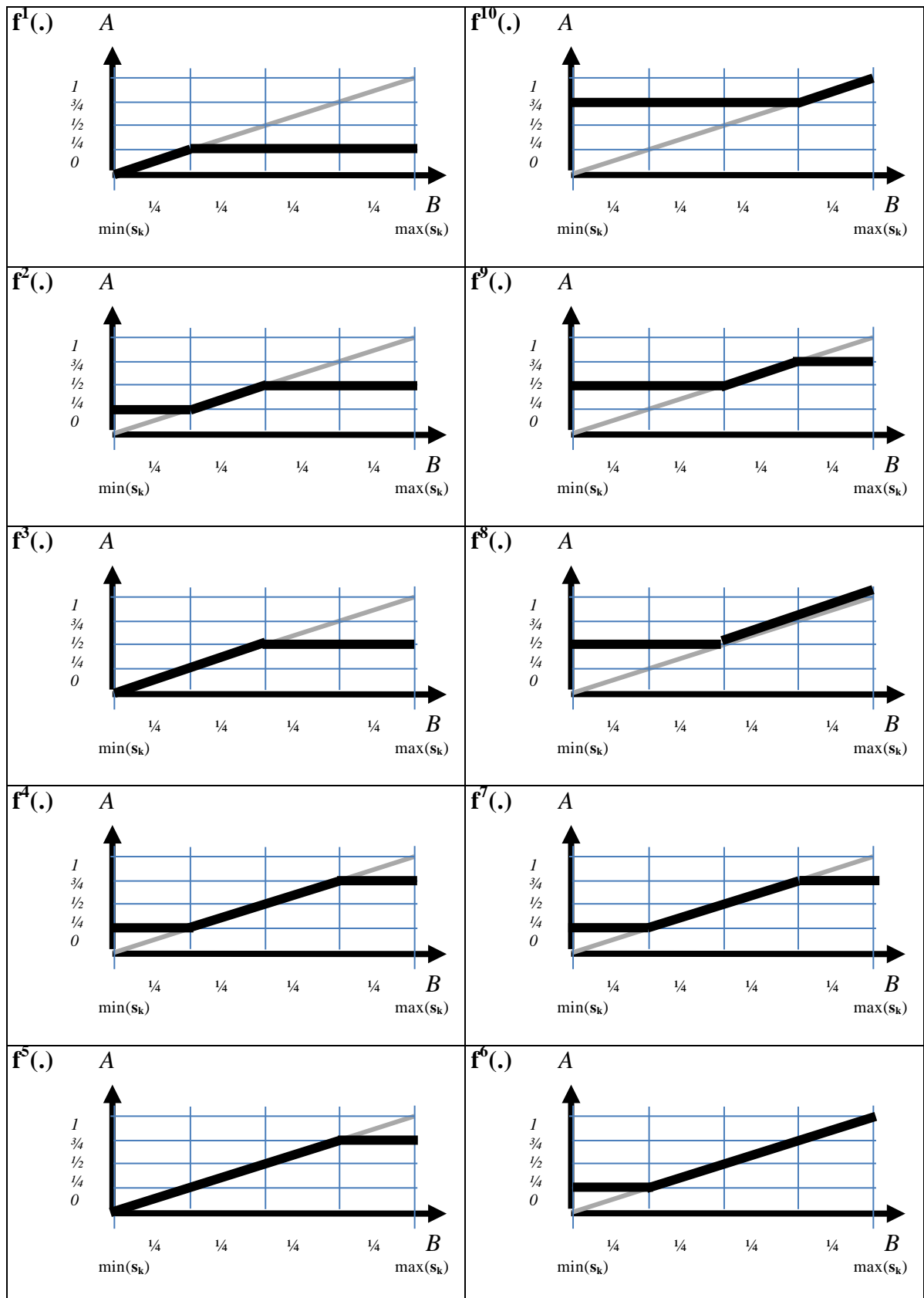


Table 2: Graphical presentation of saturation and critical mass effects in our function definitions.

It becomes visible, that functions are numbered in a way that shows some symmetry, with  $f^5(.)$  and  $f^6(.)$  being closest to the identity function,  $f^1(.)$  having the strongest saturation effect and  $f^{10}(.)$  having the strongest critical mass effect.

## 5 Results

### 5.1 Results for the linear regression models

We first show some results for the base model, regression equation (3). We run this regression twice, first with regions defined as municipalities ( $n = 813$ ) and then with regions defined as districts ( $n = 151$ ).

(a) Using municipalities ( $n = 813$ )

The five location factors can explain location advantage with a rather low R-square of 0.200. Standardized  $\beta_k$  and (one sided)  $t_k$  statistics are summarized in table 3:

Location factor $s_k$	Standardized $\beta_k$	Significance $t_k$
$s_1$ : Personal income tax	0.062	4.17%
$s_2$ : Corporate Tax	0.089	0.52%
$s_3$ : Human Capital	0.075	1.93%
$s_4$ : Building zones	0.177	0.00%
$s_5$ : Accessibility with public transport	0.258	0.00%

Table 3: Results for the linear regression models using municipalities

(b) Using districts ( $n = 151$ )

If we define regions as districts, R-square rises to 0.424. If we use municipalities there effectively seems to be some blurring by spill overs that improves with the aggregation to districts. Standardized  $\beta_k$  and  $t_k$  statistics are summarized in table 4:

Location factor $s_k$	Standardized $\beta_k$	Significance $t_k$
$s_1$ : Personal income tax	0.054	22.81%
$s_2$ : Corporate Tax	0.051	22.51%
$s_3$ : Human Capital	0.208	0.96%
$s_4$ : Building zones	0.180	2.38%
$s_5$ : Accessibility with public transport	0.341	0.02%

Table 4: Results for the linear regression models using districts

Using districts, t-statistics fall below critical values for the tax related location factors. In Switzerland, tax differentials exist on a municipal level. The respective indicators in the case of districts is a weighted average of municipal values. Data shows that variation lost through aggregation is unfavourable.

In turn, increased  $\beta$  for human capital and for accessibility using districts suggests that these location factors are most affected by spill overs if regions are small, as it is certainly the case for Swiss municipalities. The same may carry also if we use districts in Switzerland, where distances are still rather short.

As a side note, accessibility has indeed the best values for  $\beta_k$  and  $t_k$  in both cases. However, accessibility relates closely to the density of a place, so density might also account for correlation of our location advantage index and accessibility.

## 5.2 Application of functions on location factors

We now show what happens if we replace regression equation (3) with regression equation (4), introducing functions  $f^j(\cdot)$ .

The following five graphs – one for each of  $m = 5$  location factors – show values of  $\delta_k^j = \lg(t_k / t_k^j)$  on the vertical axes and for the 10 functions defined above on the horizontal axes. Remember that  $\delta$ -values above 1 or 2 will be integrated in our alternative regression model, depending on the condition chosen. Negative values should be normal, since functions cut off some information, so all negative values can be ignored. For the ten functions,  $\delta$ -value for the analysis of municipalities is showed aside the  $\delta$ -value for the analysis of districts.

**s<sub>1</sub>:**      Personal income tax

A notable  $\delta$  - value comes with our first location factor, personal income tax. In the municipality case, it reaches well above 2 if we apply functions with a critical mass floor at the average with no saturation effect as well as with saturation after the third quantile. We will continue to examine the case without saturation with its highest value  $\delta_1^8 = 3.24$ . Without critical mass, personal income has a student probability of  $t_1 = 4.17\%$ , after application of  $f^8(\cdot)$  it shrinks to  $t_1^8 = 0.0024\%$ , so condition (7b) is satisfied. In the case with districts, the value goes from a clearly non-significant level of

22.83% down to an almost highly significant level of 1.06%, what delivers  $\delta_1^8 = 1.33$  in this case, satisficing condition (7a).

This result suggests that personal income tax becomes a more relevant location factor for all those regions that have already reached an above average position, i.e. rather low personal income taxation. Below average, firms may look at other location factors and ignore the factor personal income more often.

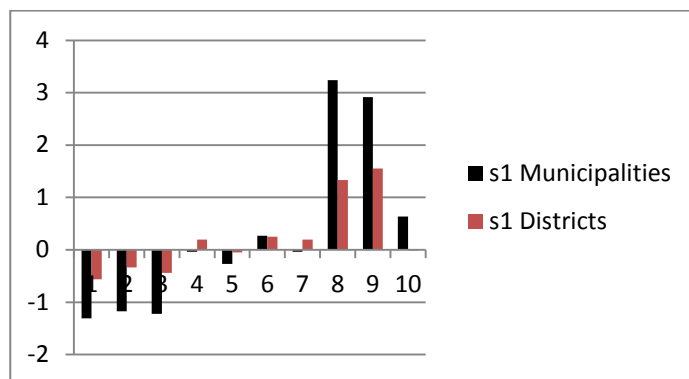


Figure 3:  $\delta$  - values for location factor  $s_1$  personal income tax

## $s_2$ : Corporate Tax

Corporate tax shows saturation in the municipality case after the first quantile already:  $\delta$  is 1.35 and  $t_2$  is significant with 0.52%, which satisfies condition (7a) but not (7b). In the district case, both conditions are not satisfied but  $\delta$  points to the same direction.

This result is fundamentally different from that found for personal taxes. It suggests a saturation effect or that corporate taxation should merely not be too expensive. While in practice some policy makers are trying to reach a top ranks for corporate taxing, in the light of this data, corporate tax heavens seem not to foster growth more than about average taxed regions.

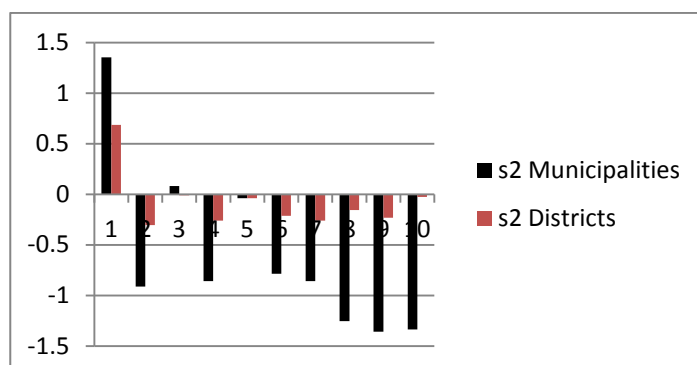


Figure 4:  $\delta$  - values for location factor  $s_2$  corporate tax

**s<sub>3</sub>:** Human Capital

Turning to the location factor human capital,  $\delta$  - values worth noting are for the district case, with a maximum of  $\delta_2^3 = 1.38$  and condition (7a) satisfied.

Similar to corporate tax, this indicates a saturation effect. According to this, having more human capital in a region would support growth only up until about average values. It only seems necessary for policy to reach an about average number of graduates in a region to foster GDP.

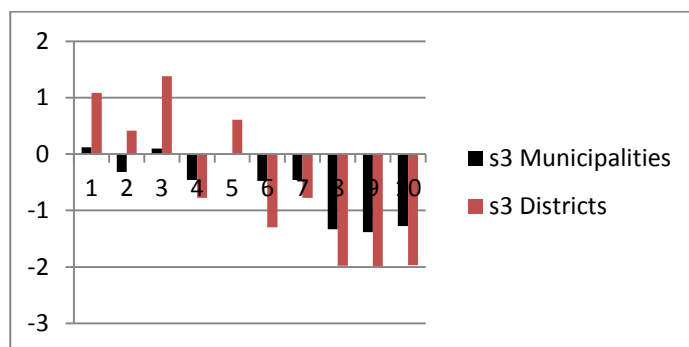


Figure 5:  $\delta$  - values for location factor  $s_3$  human capital

**s<sub>4</sub>:** Building zones with public transport

The highest  $\delta$  - value can be observed for the municipality case with a critical mass limit at the average with  $\delta_4^8 = 4.99$ . However, due to the very high significance from the base regression only condition (7a) is satisfied, but not (7b).

A priori, one could guess a saturation effect here, arguing that the lack of land would prevent growth all together while vast land reserves would not help growth further. However, we contrarily detect a critical mass effect and no saturation effect. This finding suggests that growing municipalities need to offer some choice of unbuilt land if this should be a relevant growth factor. We have to be careful with this interpretation, though, because of the high significance that the location factor building zones has in the base regression. In this sense, here the model from which we start, may be too relevant already for finding a meaningful improvement.



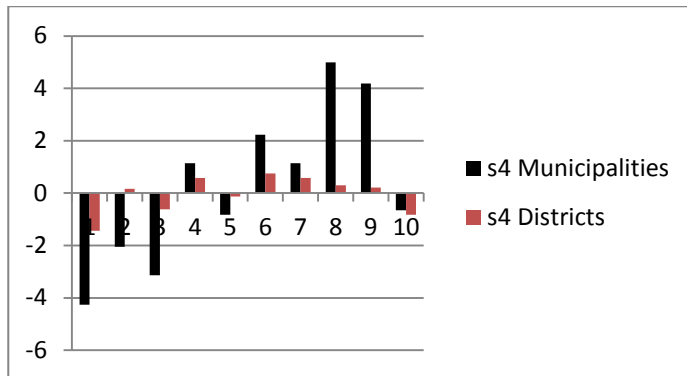


Figure 6:  $\delta$  - values for location factor  $s_4$  building zones with public transport

**$s_5$ :** Accessibility with public transport

Turning to accessibility, in the district case we observe with  $\delta_5^2 = 3.66$  a value well above two, suggesting that a critical mass effect after the first quartile and a saturation effect after the average would strongly improve significance. However again,  $t_5 = 0.022$  is “too good” and therefore condition (7b) is satisfied, but not (7a).

$\delta_5^2$  means a critical mass effect after the first and a saturation effect after the second quantile which implies that accessibility should ideally reach a certain level, but needs not to be excellent in order to promote growth. It seems intuitive, that accessibility should meet a minimum standard but becomes luxurious after a certain level.

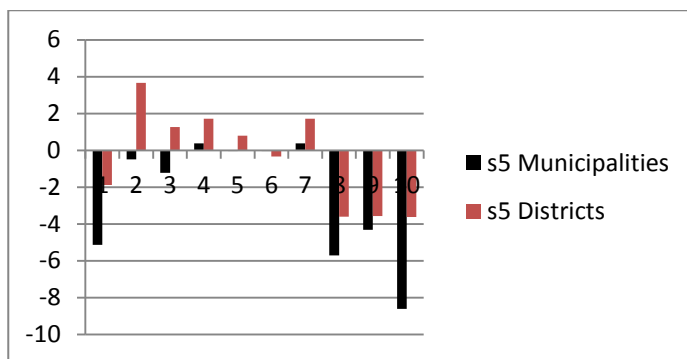


Figure 7:  $\delta$  - values for location factor  $s_5$  accessibility with public transport

### 5.3 Results for a non-linear regression model in the municipality case

We start the reformulation of non-linear regression models including only those cases that satisfy our stricter condition (7b). There are only two cases, namely for location

factor personal income tax and  $f^8(.)$  and  $f^9(.)$ . Since  $\delta_1^8 > \delta_1^9$  and since  $f^8(.)$  cuts off less information than  $f^9(.)$ , we test regression equation

$$(10) \quad \mathbf{a} = \mathbf{S}_1^8 \boldsymbol{\beta}_1^8 + \mathbf{u}_1^8$$

With modified personal income tax data, location advantage is explained with R-square 0.213, a slight increase compared to the original model with R-square 0.200. Standardized  $\beta_k$  and t-statistics are summarized in the following table 5:

Location factor $\mathbf{s}_k$	Standardized $\beta_k$	Significance $t_k$
$\mathbf{s}_1$ : Personal income tax	0.145	0.00%
$\mathbf{s}_2$ : Corporate Tax	0.052	6.96%
$\mathbf{s}_3$ : Human Capital	0.073	1.99%
$\mathbf{s}_4$ : Building zones	0.155	0.02%
$\mathbf{s}_5$ : Accessibility with public transport	0.261	0.00%

Table 5: Results for the linear regression models using municipalities

Table 5 shows, that for  $\mathbf{s}_1$  not only t-statistics improve as it is implied by definition (6) for  $\delta$ , but standardized  $\beta_1$  rises from 6.2% to 14.5%. While  $\beta_3$ ,  $\beta_4$  and  $\beta_5$  increase as well,  $\beta_2$  decreases. The location factor personal income tax becomes highly significant, despite having no variation in 489 out of  $n = 813$  observed values anymore.

Allowing for the less strict condition (7a), three location factors can be included into the revised model, i.e. personal income tax, corporate tax and building zones. We denote this by inserting three respective subscripts into (4):

$$(11) \quad \mathbf{a} = \mathbf{S}_1^{8 \ 1 \ 4} \boldsymbol{\beta}_1^{8 \ 1 \ 4} + \mathbf{u}_1^{8 \ 1 \ 4}$$

Running this regression, R-square rises from 0.200 to 0.245. Table 6 shows further results:

Location factor $\mathbf{s}_k$	Standardized $\beta_k$	Significance $t_k$
$\mathbf{s}_1$ : Personal income tax	0.162	0.00%
$\mathbf{s}_2$ : Corporate Tax	0.114	0.02%
$\mathbf{s}_3$ : Human Capital	0.041	11.72%
$\mathbf{s}_4$ : Building zones	0.277	0.00%
$\mathbf{s}_5$ : Accessibility with public transport	0.213	0.00%

Table 6: Results for the linear regression models using municipalities

Standardized  $\beta_i$  rises for those location factors that were changed. However, human capital  $s_3$  loses not only in  $\beta_3$ , but also in significance. Location factor  $s_3$  can actually be removed from this last model. This alters values for R-square only to 0.244 and all other results change only marginally as well. The results are shown in Table 7:

Location factor $s_k$	Standardized $\beta_k$	Significance $t_k$
$s_1$ : Personal income tax	0.163	0.00%
$s_2$ : Corporate Tax	0.111	0.03%
$s_4$ : Building zones	0.293	0.00%
$s_5$ : Accessibility with public transport	0.216	0.00%

Table 7: Results for the linear regression models using municipalities

#### 5.4 Results for a non-linear regression model in the district case

Turning to the 151 districts, no location factor can satisfy (7b), but in three cases condition (7a) is satisfied, namely for personal income tax, for human capital and for accessibility.

In the same way as in (11), we formulate a non-linear regression equation as

$$(12) \quad \mathbf{a} = \mathbf{S}_1^9 \mathbf{S}_3^3 \mathbf{S}_5^2 \boldsymbol{\beta}_1^9 \mathbf{S}_3^3 \mathbf{S}_5^2 + \mathbf{u}_1^9 \mathbf{S}_3^3 \mathbf{S}_5^2$$

Estimating (12) shows an R-square that has a now higher value of 0.520 compared to 0.424 from the base model.

Location factor $s_k$	Standardized $\beta_k$	Significance $t_k$
$s_1$ : Personal income tax	0.191	0.16%
$s_2$ : Corporate Tax	0.013	41.68%
$s_3$ : Human Capital	0.235	0.15%
$s_4$ : Building zones	0.135	4.09%
$s_5$ : Accessibility with public transport	0.419	0.00%

Table 8: Results for the linear regression models using municipalities

Those location factors without transformation,  $s_2$  and  $s_4$ , end up with the least  $\beta_k$  and significance level. Corporate tax becomes insignificant and should be eliminated. This leaves R-square,  $\beta$ s and significance levels practically untouched. Elimination of a second location factor, building zones, still allows a regression with an R-square of 0.510,

while all location factors are highly significant. The corresponding results are shown in Table 9:

Location factor $s_k$	Standardized $\beta_k$	Significance $t_k$
$s_1$ : Personal income tax	0.226	0.01%
$s_3$ : Human Capital	0.293	0.00%
$s_5$ : Accessibility with public transport	0.451	0.00%

Table 9: Results for the reduced linear regression models using municipalities

If we went back to the base model without non-linearities, the otherwise same regression with  $s_1$ ,  $s_3$  and  $s_5$  would deliver an R-square of 0.407 and less significant t-statistics.

## 6 Conclusions

In our quest for non-linear location factors we found several suspects.

Personal income tax appears to be relevant more in regions where it is already above average. The rationale behind this may be that some firms are more sensitive to this location factor than others. The more sensitive ones will avoid regions with personal income taxes above average anyway, making this location factor less relevant in these regions while the less sensitive firms ignore this location factor all together. This finding has a stronger statistical argument compared to rest of suspects.

Corporate tax seems to resemble a hygiene factor: corporate tax hinder growth if they become too expensive. If they are better than the worst quarter, they do not make a relevant difference anymore. This saturation effect contrasts not only with the finding for personal income tax, but also with many tax policies in Swiss Cantons and municipalities.

If regions are defined as districts, we find again a saturation effect for human capital. While a lack of human capital seems to hinder growth, above average levels of graduates in a region have no further impact on GDP.

Turning to building zones, we find a critical mass effect for the municipalities. Maybe somewhat against intuition, available building zones must reach a certain level in order to become relevant for growth.

Finally, in the case of districts, we find a critical mass effect and a saturation effect for accessibility with public transport. This implies for regional policy that accessibility should neither be a bottleneck nor a luxury.

In this paper, non-linearities were induced with a limited number for functions. Instead of critical mass floors and satisficing ceilings, functions like logarithms or tangential functions could be tested, just to mention two other possibilities.

Also using the same functions, the quest for non-linearities may continue and further research could check or add to our findings, including testing in other countries, with different base models or with methodological alternatives.

## 7 Literature

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