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REGULAR ISSUE

Impact of clusters on regional economic performance

A methodological investigation and application in the case of the precision goods sector in Switzerland

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Abstract

Purpose – This paper aims to examine the methodology used to identify clusters on the one hand and assess the economic impact that those may have on regions on the other hand.

Design/methodology/approach – The influential work on "clusters"lead by Michael Porter since the 1990s has become a tool for promoting innovation and growth at national and regional level. Even if the theory has become very popular, a few empirical investigations were conducted since. In a recent study, Delgado, Porter and Stern developed a model to investigate the impact of cluster composition on the performance of regions in the USA. They find strong evidence that industries operating in a strong cluster environment perform better. The aim of this study is to improve the methodology used in evaluating the cluster environment and then to replicate their model and apply it to a highly competitive industry in Switzerland, namely, the precision goods sector. It enables to look closely at the importance of the microeconomic environment surrounding an industry at the regional level.

Findings – In Switzerland, the precision industry forms a traded cluster in three different regions. The model then reveals that those regions perform better. The results show that industries located in or nearby regions with a strong cluster environment experience higher employment growth rates.

Originality/value – It highlights the importance of the microeconomic environment even in small competitive countries.

Keywords Clusters, Regional competitiveness, Cluster empirics, Empirical methodology

Paper type Research paper

1. Introduction

The economic performance of regions is a key issue that has attracted considerable attention in the academic community, as well as in the government, among those in charge of economic development (Huggins and Thompson, 2014; Perucca, 2014; Porter, 1990, 2003; van Oort *et al.*, 2015). A crucial question relates to the important disparities among the economic performances of regions located in the same country and, more specifically, to the drivers of regional economic performance. From Marshall (1890,

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2006) to Porter (1990, 2003, 2008), scholars have scrutinized and identified the role of clusters in fostering the competitiveness of regions due to so-called "agglomeration effects" (Camagni *et al.*, 2015; Cusmano *et al.*, 2014; Hervas Oliver *et al.*, 2015; Karlsson *et al.*, 2014; Lazzeretti *et al.*, 2014; Pires *et al.*, 2013; Rigby and Brown, 2015; Yamashita *et al.*, 2014;) and their related "specialization effects" (Kemeny and Storper, 2015, p. 1,007; Okubo and Tomiura, 2014; Rauch, 2014).

Since the 1990s, the theory on clusters has become an important concept for promoting growth and innovation at both the national and regional levels (Sölvell, 2015; Huggins and Izushi, 2015). To date, very few studies have been able to measure the real impact of clusters and cluster policies (Aranguren *et al.*, 2014; Kahl and Hundt, 2015) or the impact of specific proximity effects (Broekel, 2015). The first challenge is to precisely identify the geographical boundaries of clusters, as well as the industries competing within these clusters (Catini *et al.*, 2015). If this first issue can be successfully addressed, a second challenge relates to the methodologies and measurement tools assessing the clusters' impact on the economic development of regions. Among the crucial points is the extraction of the influence of clusters from other factors impacting economic performance of regions. In that respect, it is necessary to distinguish "convergence effects" and "agglomeration effects" (Delgado *et al.*, 2014, p. 1785). Finally, the availability of data, which are difficult to collect for narrow geographical spaces, determines the ability to obtain any result. The purpose of this paper is to address those challenges in the case of the precision engineering sector. Our approach is based on the study "clusters, convergence and economic performance" published by Delgado *et al.* (2012); a shorter version was published in 2014.

The paper contains four sections. The next section provides a rigorous identification of precision engineering clusters in Switzerland. The approach identifies the regions (in our case "districts") that host these clusters, as well as the main industries that form these clusters. The third section presents the methodology, data and variables used to assess the role of these clusters on the economic performances of regions where these clusters are located. A forth section reveals the results, and a fifth provides a discussion of these results.

2. Identification of clusters in the field of the "precision engineering sector" in Switzerland

The most common tool to identify clusters and, more specifically, industrial specialization/concentration in a region is the location quotient (LQ) (Delgado *et al.*, 2014, p. 1791; Crawley *et al.*, 2013, pp. 1854-1855). According to Strotebeck:

> The location quotient (LQ) can be used to see if the employment of an industry in a subregion is above or below the average. The average is given by the employment share of the industry regarding the overall employment in the nation (Strotebeck, 2010, p. 3).

The LQ reflects the degree of concentration/specialization of an industry in a given region compared with its concentration in the national economy (Delgado *et al.*, 2012, p. 21). Therefore, the LQ can be shown as (Strotebeck, 2010, p. 3):

$$LQ_{i,r} = \frac{E_{i,r}/E_r}{E_{i,n}/E_n} \tag{2.1}$$

Where $E_{i,r}$ is the employment of industry i in region r, and $E_{i,n}$ is the employment of that same industry in nation n. E_r and E_n are the overall employment of region r and nation n, respectively.

When the LQ takes a value above one, it indicates that the industry is over-represented in the region[1]. The opposite deduction can be made when the LQ takes a value between zero and one. However, this conclusion may be achieved by two different means that may have consequences when defining the border of a cluster (Strotebeck, 2010, p. 5). A value above one can be the result of a high concentration of small firms in a particular region, or, for example, there could be one or two large firms in that region-industry that raise the LQ's value. Therefore, it is essential to examine what makes an LQ go above one: the number of firms and/or their size. In his paper, Strotebeck (2010) used the following methodology developped by Holmes and Stevens (2002) and applied it to the German biotechnology industry. In accordance with the methodology of Holmes and Stevens (2002), the standard LQ, $Q^x_{i,r}$, can be rewritten as the product of a plant quotient, $Q^n_{i,r}$, and a size quotient, $Q^s_{i,r}$:

$$Q^x_{i,r} \equiv Q^n_{i,r} \times Q^s_{i,r} \tag{2.2}$$

Where:

$$Q^x_{i,r} = \frac{E_{i,r}/E_r}{E_{i,n}/E_n} \tag{2.3}$$

$$Q^n_{i,r} = \frac{n_{i,r}/E_r}{n_i/E_n} \tag{2.4}$$

$$Q^s_{i,r} = \frac{E_{i,r}/n_{i,r}}{E_{i,n}/n_i} \tag{2.5}$$

Where $n_{i,r}$ is the number of firms in industry i in region r, and n_i is the number of firms of that same industry i in nation n. The plant LQ and the size quotient can be observed separately from each other. Therefore, it is possible to analyze whether the value of a LQ is driven by the plant LQ and/or by the size quotient. Holmes and Stevens develop a methodology based on two betas (one for each effect) that show the relation of each quotient with the LQ. The researchers first take the natural logs of each quotient of equation (2.2) and let $q^x_{i,r}$, $q^n_{i,r}$, $q^s_{i,r}$ be the natural logs of $Q^x_{i,r}$, $Q^n_{i,r}$ and $Q^s_{i,r}$:

$$q^x_{i,r} \equiv q^n_{i,r} + q^s_{i,r} \tag{2.6}$$

The relation between the level of plants and concentration is defined by:

$$\beta_n = \frac{\mathrm{cov}\,(q^n_{i,r};\ q^x_{i,r})}{\mathrm{var}\,(q^x_{i,r})} \tag{2.7}$$

In contrast, the relation between firm size and concentration is given by:

$$\beta_s = \frac{\mathrm{cov}\,(q^s_{i,r};\ q^x_{i,r})}{\mathrm{var}\,(q^x_{i,r})} \tag{2.8}$$

In the extreme case, where $\beta_n = 1$, the variation in industry concentration is entirely defined by a variation in the number of firms (Strotebeck, 2010, p. 6). As Martin and Sunley (2003, p. 10) noted, "*The obvious problem raised by these cluster definitions is the lack of clear boundaries, both industrial and geographical*". Although it can be easy to regroup different industries with clearly linked businesses, it can occasionally be tricky to observe complementarities and relations between other industries, more so when these boundaries are continually evolving over time, notably for the precision engineering sector. Porter (2008, p. 218) admits the following: "*Drawing cluster boundaries is often a matter of degree, and involves a creative process*". To decide whether there are any clusters of precision industries in Switzerland, a closer examination must be made of the industries that may compose the clusters.

The precision engineering sector is composed of various industries belonging mainly to the group of MEMS technologies (MicroElectroMechanical Systems) and the watchmaking business (Berne Economic Development Agency, 2010, p. 2). Based on studies dedicated to the precisions businesses competing in Switzerland (Berne Economic Development Agency, 2010, p. 2; Micronarc, 2015; OSTAJ, 2013, p. 3; Rossel, 2013, pp. 23-24), we identified 12 core industries (Table I), as well as eight complementary industries (Table II). The core industries represent 23 per cent of manufacturing employment in Switzerland.

Regarding the geographical units, we focus on "districts". The Swiss territory is divided into 147 districts (data in 2011; Federal Statistical Office 2015a). We identified 70 districts where the core industries register an LQ above 1. The significant majority of districts identified are located in one of the three following regions: the northeastern part of Switzerland, the central part of Switzerland and the western part of Switzerland

	Core industries in NOGA-3 (2008)
Code	Definition
256	Treatment and coating of metals; machining
257	Manufacture of cutlery, tools and general hardware
261	Manufacture of electronic components and boards
265	Manufacture of instruments and appliances for measuring, testing and navigation; watches and clocks
266	Manufacture of irradiation, electromedical and electrotherapeutic equipment
271	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus
281	Manufacture of general-purpose machinery
282	Manufacture of other general-purpose machinery
284	Manufacture of metal forming machinery and machine tools
289	Manufacture of other special-purpose machinery
303	Manufacture of air and spacecraft and related machinery
325	Manufacture of medical and dental instruments and supplies

Source: Based on Federal Statistical Office (2008a)

Table I. Core industries of the precision goods sector in NOGA-3

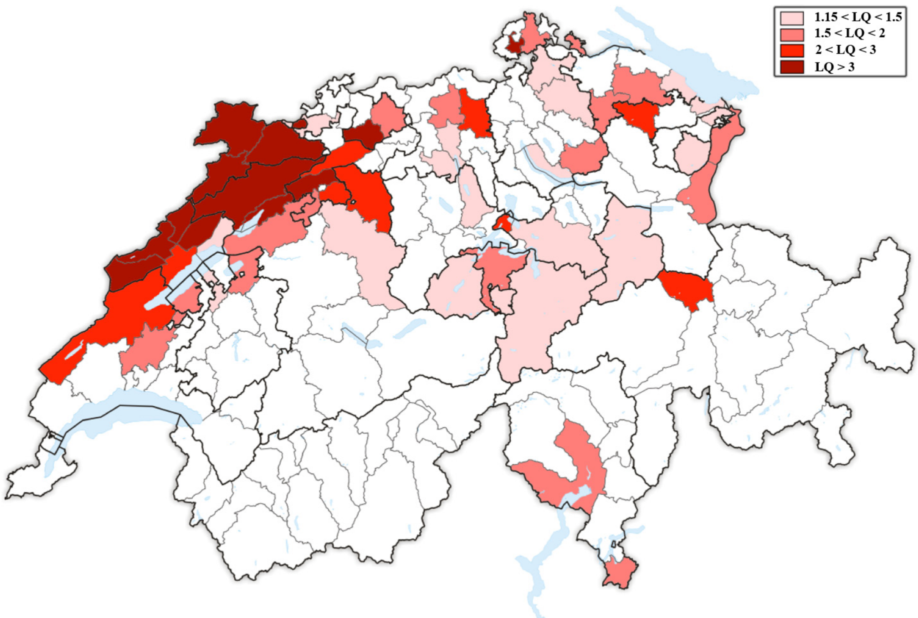
(Figure 1). This latter is the major region with the strongest concentration index and is characterized by the strong presence of the watchmaking industry.

At this stage, it is still not possible to conclude the presence of a precision engineering cluster in each of these three regions. As stated above, it is necessary to identify whether the concentration index (LQ) is due to the size of firms, the density of firms or both. In the first case, we could barely conclude that the high concentration ratio would reflect the presence of a cluster. The plan quotient and the size quotient have been computed according to equations (2.2) and (2.6), and the influence of the size of firms and the

Table II. Complementary industries of the precision goods sector in NOGA-3

Code	Complementary industries in NOGA-3 (2008) Definition
244	Manufacture of basic precious and other non-ferrous metals
245	Casting of metals
251	Manufacture of structural metal products
255	Forging, pressing, stamping and roll-forming of metal; powder metallurgy
259	Manufacture of other fabricated metal products
321	Manufacture of jewelry and related articles
331	Repair of fabricated metal products, machinery and equipment
332	Installation of industrial machinery and equipment

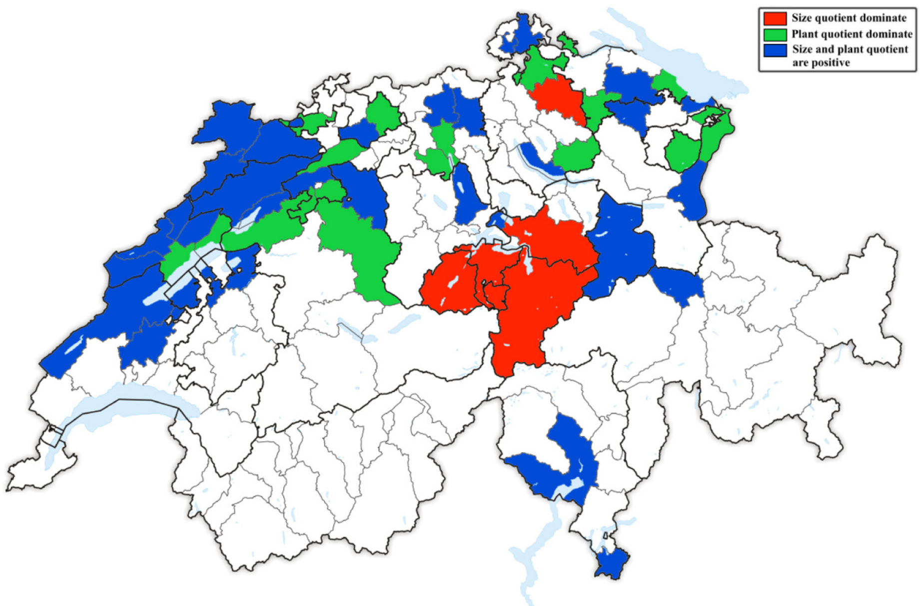
Source: Based on Federal Statistical Office (2008a)



Note: The map shows districts as defined in 2011
Sources: Based on Federal Statistical Office (2015b); STATENT (2012)

Figure 1. Location quotient for the precision goods sector in 2012 (NOGA-3)

concentration of firms is computed on the basis of equations (2.7) and (2.8) (Figure 2). For the 70 districts that have an LQ above 1, the plant quotient has an explanatory force of 67 per cent, and the size of the firm is 33 per cent (β_n = 0.6664 and β_s = 0.3336). Therefore, the number of firms explains two thirds of the value of the LQs above one. The first conclusion to be drawn is that the higher LQ values are driven by the concentration of numerous firms, not their size, which reflects a cluster dynamic. Districts in the western part of Switzerland have LQs that are driven by the number of firms (plant quotient is positive, and size quotient is negative) or by both effects (plant and size quotients are positive). The northeastern part of Switzerland shows the same feature, with the exception of one district, which is size driven. In contrast, the central part of Switzerland shows LQs above one that are the result of the dominance of the size quotient. In these districts, the concentration of firms is lower. However, the number of firms remains important when looking at the absolute size; thus, we may also consider the central part of Switzerland as the recipient of a precision industrial sector cluster. The three clusters are primarily composed of manufacturing industries that represent 45 per cent of the manufacturing value added in Switzerland (Berne Economic Development Agency, 2010, p. 2). The clusters can be classified as "traded clusters" according to Porter's (2003, p. 559) methodology, the main criteria of which state that the mean LQ of the top five districts must be equal to or above 2, the LQ-based Gini index must be equal to or above 0.3, and the employment shares of districts with an LQ above 1 must represent more than 50 per cent of the national employment.



Note: The map shows districts as defined in 2011
Sources: Based on Federal Statistical Office (2015b); STATENT (2012)

Figure 2. Plant and size quotient for the precision goods sector in 2012 (NOGA-3)

3. Precision engineering clusters impact on regional performance

The economic literature argues that clusters may impact the economic performance of regions according to various indicators such as employment, productivity, innovation, firm creation and/or expansion, firm entry, firm survival and regional resilience (Bottazzi and Gragnolati, 2015; Brakman and van Marrewijk, 2013; Cohendet *et al.*, 2014; Frenken *et al.*, 2015; Hazir *et al.*, 2014; He *et al.*, 2014; Kiese and Hundt, 2014; Pires *et al.*, 2013). As indicated above, there are few studies that offer methodological tools and empirical evidences on the impact of clusters on the economic performance of regions (Trippl *et al.*, 2015). Among these, Delgado *et al.* (2014) developed a rigorous methodology based on US regions. The main indicator scrutinized in their study is the employment growth that may be induced by clusters. Our attempt to evaluate the role of precision engineering clusters in Switzerland on the economic performances of region where these clusters are located is based on the Delgado *et al.* study. We followed their methodology as closely as possible. Whereas their study focused on 41 different clusters comprising 589 traded industries, our contribution is concentrated on one significant type of cluster (clusters in the precision engineering sector). We also introduced certain methodological adaptations where our sample and the lack of availability of data obliged us to depart from the researchers' original study.

The performances of regions do not solely depend on the clusters presence. As highlighted by Delgado *et al.* (2014, p. 1785), two countervailing forces are at work when examining the economic performance of a particular region as follows: convergences forces and agglomeration forces. According to the growth theory, convergence forces reduce the differences among regions (Barro and Sala-i-Martin, 1992), whereas agglomeration forces, which are induced by clusters, increase the inequalities among regions (Porter, 1990). In their paper, Delgado *et al.* (2014, p. 1786) separate both convergence and agglomeration forces using the cluster theory. The researchers state that convergence may arise not only at the region level but also in a narrower unit of analysis, namely, the region-industry level (e.g. a particular industry in a specific region) (Delgado *et al.*, 2014, p. 1785; Kim *et al.*, 2015). The researchers developed a statistical model that considers the convergence effects at "the region-industry level", whereas computing agglomeration effects operate across closely related industries. According to them:

> Conditional convergence operating at narrower economic units (e.g. within a single industry) can coexist with agglomeration across related economic units (e.g. across industries within a cluster) (Delgado *et al.*, 2012, p. 4).

3.1 Methodology

Delgado *et al.* (2012) developed three models, the so-called "industry growth model", the "cluster growth model" and the "region growth model". These models differ from each other according to the level of aggregation of the dependent variable. The first model ("industry growth model") measures the effect of the cluster on each industry. The second model ("cluster growth model") computes the effect of the cluster on all cluster components. The third model ("region growth model") focuses on a more aggregate unit, namely, the region. This third model measures the effects of all strong clusters located in a region on the region's economic performance (Delgado *et al.*, 2012, p. 16). This model considers the results of studies noting the relations among clusters (Lu and Reve, 2015).

As indicated above, our study limits its scope to one type of cluster, which contrasts with the Delgado *et al.* study. Therefore, without information regarding the existence of clusters other than the precision engineering sector in each region of Switzerland, our analysis focuses on the first two models developed by Delgado *et al.* as follows: the "industry growth model" and the "cluster growth model".

3.1.1 The "industry-growth model". This first model explains the growth at the "region-industry level". It is argued that although convergence arises in a narrower unit of analysis (i.e. region-industry level), agglomeration forces occur at the cluster level (Delgado *et al.*, 2014, p. 1788). On the basis of the "original model" (Delgado *et al.*, 2012, p. 13), we formulate the model as follows:

$$\begin{aligned}\ln\left(\frac{Employ_{icr,2012}}{Employ_{icr,2005}}\right) &= \alpha_0 + \delta \ln(Industry\ Spec_{icr,2005}) \\ &+ \beta_1 \ln(Cluster\ Spec^{outside\ i}_{icr,\ 2005}) \\ &+ \beta_2 \ln(Related\ Cluster\ Spec^{outside\ c}_{cr,\ 2005}) \\ &+ \beta_3 \ln(Cluster\ Spec\ in\ Neighbors_{cr,2005}) + \alpha_i + \alpha_r + \varepsilon_{icr}\end{aligned} \quad (3.1)$$

The dependent variable is the employment growth of the industry i in cluster c (precision engineering cluster) in a given region (district) r for a seven-year period (2005-2012). To control for convergence and agglomeration effects, one must focus on the initial level of employment (2005). All explanatory variables are specified for the initial year 2005. The first explanatory variable (*industry spec*) controls for convergence effects. In fact, it was previously explained that convergence effects arise at this narrower unit of analysis. The *industry spec* variable computes the initial level of employment at the region-industry level (district-industry level).

The following three explanatory variables measure the strength of the cluster environment in a specific district and in the surrounding districts (Delgado *et al.*, 2014, p. 1789). The variable *cluster specialization outside industry i* reflects "*the strength of the cluster around that industry*". The related cluster specialization variable measures the specialization of closely related clusters in the same district. This variable can be justified by the fact that two clusters may share common knowledge or the same pool of specialized inputs (Porter, 2000, p. 18). The fourth explanatory variable is the *cluster specialization in neighboring* districts (adjacent to the studied district). The coefficients of these three explanatory variables (β_1, β_2 and β_3) are expected to take a positive value, which will reflect agglomeration forces.

After controlling for convergence and agglomeration effects, which is accomplished using the four explanatory variables, the "*differences across regions and industries that influence the growth of employment*" may remain (Delgado *et al.*, 2012, p. 14). Therefore, two fixed effects are included in the model to control for differences across industries and regions as follows: α_i represents the industry fixed effect, and α_r represents the region fixed effect. As the authors note in their paper:

> This specification examines the impact of the level of industry specialization and the strength of the cluster environment, fully controlling for differences in the average growth of a region or the average growth of a particular industry (Delgado *et al.*, 2012, p. 14).

Although the industry fixed effect is based on the number of industries used in the paper, the region fixed effect does not use the district as a parameter. Districts in Switzerland are excessively small to consider political decisions or economic and demographic tendencies. A classification of larger regions developed by the Federal Statistical Office (FSO) is used that splits the Swiss territory into seven different regions[2].

However, one problem remains when using this original formula developed by Delgado *et al.* According to the statistical constraints of data available in Switzerland, considering the employment data for 2005, in particular, we need to rely on a two-digit classification (NOGA-2); therefore, we must depart from the three-digit classification (NOGA-3). Table III presents the differences between both classifications. According to NOGA-2, our sample is composed of six industries (composed of several sub-sectors identified according to the NOGA-3 classification).

According to the two-digit classification (NOGA-2), the complementary industries (noted in Table II) are already included in the definition of the cluster. Therefore, in the "industry growth model", the third explanatory variable (*related cluster spec*) is no longer essential. In fact, those complementary industries are already included in the cluster definition of precision engineering industries, which is represented in the equation by the second explanatory variable (*cluster spec outside i*). Therefore, the model developed in the original paper is changed to the following equation in which the third explanatory variable is removed (*related cluster spec*):

NOGA classification (2008)		
Industries NOGA-3 (2008)	Industries NOGA-2 (2008)	Description
244	24+25	Manufacture of basic metals
245		
255		
256		Manufacture of fabricated metal products, except machinery and equipment
257		
259		
261	26	Manufacture of computer, electronic and optical products
265		
266		
271	27	Manufacture of electrical equipment
281	28	Manufacture of machinery and equipment n.e.c.
282		
284		
289		
303	29+30	Manufacture of motor vehicles, trailers and semi-trailers Manufacture of other transport equipment
321	31-33	Manufacture of furniture
325		Other manufacturing
331		Repair and installation of machinery and equipment
332		

Note: Complementary industries are noted in Italic
Source: Based on Federal Statistical Office (2008a, p. 22)

Table III.
Comparison NOGA-3 and NOGA-2 classification for the precision goods sector

$$\ln\left(\frac{Employ_{icr,\,2012}}{Employ_{icr,\,2005}}\right) = \alpha_0 + \delta \ln\left(Industry\ Spec_{icr,\,2005}\right) + \beta_1 \ln\left(Cluster\ Spec^{outside\ i}_{icr,\ 2005}\right) + \beta_2 \ln\left(Cluster\ Spec\ in\ Neighbors_{cr,\,2005}\right) + \alpha_i + \alpha_r + \varepsilon_{icr} \quad (3.2)$$

3.1.2 The "cluster growth model". This model reflects the link between the employment growth of a specific cluster and the regional environment of this cluster (Delgado *et al.*, 2012, pp. 15-16). Whereas the first model aimed to explain the influence of the cluster environment on the employment growth of the specific industry located in this region, the second model focuses on the cluster environment impact on the employment growth at the cluster level. In this model, in contrast to the "industry growth model", employment growth is computed at the region-cluster level, which is more aggregated than the region-industry level. Therefore, the dependent variable is the employment growth of cluster c in region r for the 2005-2012 period. The model may be formulated as follows:

$$\ln\left(\frac{Employ_{cr,\,2012}}{Employ_{cr,\,2005}}\right) = \alpha_0 + \delta \ln\left(Cluster\ Spec_{cr,\,2005}\right) + \beta_1 \ln\left(Related\ Cluster\ Spec^{outside\ c}_{cr,\ 2005}\right) + \beta_3 \ln\left(Cluster\ Spec\ in\ Neighbors_{cr,\,2005}\right) + \alpha_c + \alpha_r + \varepsilon_{cr} \quad (3.3)$$

The equation also must control for convergence forces that may arise at the cluster level. The first explanatory variable computes the level of employment of the cluster for the initial year of 2005. The sign of the coefficient δ of the first explanatory variable is ambiguous; it depends on "the relative impact of convergence and agglomeration" at the cluster level (Delgado *et al.*, 2014, p. 1789). There are two explanatory variables that control for agglomeration forces, namely, the role of related clusters and similar clusters in neighboring regions (districts). The sign of their coefficients is expected to be positive. The third explanatory variable considers the cluster environment of adjacent regions. The stronger the cluster environment in adjacent regions, the higher the employment growth should be at the cluster level (Delgado *et al.*, 2012, p. 16). In summary, although the sign δ is ambiguous, β_1 and β_2 are expected to take positive values (Delgado *et al.*, 2012, p. 16). It is also necessary to control for differences that arise from specific characteristics of a given cluster or region. Therefore, two fixed effects are added to the model as follows: cluster and region fixed effects (α_c and α_r, respectively). Similar to the "industry growth model", the region fixed effect uses larger regions defined by the FSO rather than districts as parameters.

Similar to the previous model, the second explanatory variable (*related clusters spec*) will be removed. As explained above, this elimination is due to the two-digit classification. A second modification has been made regarding the fixed effects. The role of a fixed effect is to control for unobserved differences between regions or different clusters (e.g. differences between the chemical cluster and the precision engineering cluster). Although the model developed by Delgado *et al.* focused on a set of clusters within the USA, we focus solely on one cluster. Therefore, there is no need to introduce a fixed effect regarding the cluster (α_c). The original equation has been modified as follows:

$$\ln\left(\frac{Employ_{cr,2012}}{Employ_{cr,2005}}\right) = \alpha_0 + \delta \ln(Cluster\ Spec_{cr,2005}) + \beta_1 \ln(Cluster\ Spec\ in\ Neighbors_{cr,2005}) + \alpha_r + \varepsilon_{cr} \quad (3.4)$$

3.2 Data and variables

The data are provided by the FSO. Structural Business Statistics (STATENT), which is a department of the FSO, takes a census of the number of firms, the number of jobs and the number of full-time equivalent (FTE) jobs (Federal Statistical Office, 2015b). Due to the modification of methodologies used by the FSO, certain biases are not excluded when using those data[3]. The empirical analysis is based on the number of full-time employment jobs for the years 2005 and 2012. The choice of the starting year (2005) is because there are no data available before that year. The regions considered are the "districts". Our sample is composed of the six different traded industries of the precision engineering cluster. We consider the 147 districts that cover the entire territory of Switzerland. All precision industries that have less than a hundred FTE jobs in a district are excluded. In total, the sample counts 748 observations. Therefore, the scope of our study is narrower than the Delgado *et al.* sample. The researchers use 55,083 observations based on 589 traded industries regrouped into 41 types of traded clusters, which cover the entirety of the continental USA [179 economic areas (EAs)] (Delgado *et al.*, 2012, p. 20).

3.2.1 Dependent variable. The dependent variable is a performance measure that is represented by the employment growth at the region-industry level for the "industry growth model" and at the cluster level for the "cluster growth model". As presented above, the variable is calculated as follows: $\ln(Employ_{icr,2012}/Employ_{icr,2005})$ for the first model and $\ln(Employ_{icr,2012}/Employ_{icr,2005})$ for the second one (Delgado *et al.*, 2012, p. 20). Therefore, the computed value is the growth rate of employment for a seven-year period. Based on the 748 observations, the region-industry-based dependent variable has a mean of 4.26 per cent, and the region-cluster level registers a mean of 5.76 per cent.

3.2.2 Explanatory variables. The measure of the specialization of each industry in each region (district), which is based on the LQ, allows one to control for the presence of convergence and agglomeration effects (Delgado *et al.*, 2012, p. 20). The LQ approach also measures the strength of an industry or cluster in a region. Therefore, all explanatory variables are computed in accordance with the equation (2.1). The first explanatory variable is the specialization of a specific industry for a particular district:

$$Industry\ Spec_{Employ,ir,2005} = \frac{E_{ir}/E_r}{E_{i,CH}/E_{CH}} \quad (3.5)$$

Where $E_{i,r}$ is the employment of industry i in district r, and $E_{i,CH}$ is the employment of that same industry on the national level. Using the 748 observations, this first variable has a mean of 1.47 and a variance of 4.81.

The second variable is the specialization of the cluster outside the studied industry. This enables measurement of the cluster environment around that particular industry:

$$Cluster\ Spec_{icr}^{outside\ i} = \frac{E_{cr}^{outside\ i}/E_r}{E_{c,CH}^{outside\ i}/E_{CH}} \tag{3.6}$$

Where $E_{c,r}^{outside\ i}$ is the employment of the cluster c in district r outside industry i, and $E_{c,CH}^{outside\ i}$ is the equivalent measure on the national level. This variable has an average of 1.36 and a variance of 0.82.

The third variable reflects the specialization of a cluster in a given district. This time, all industries of the cluster are considered:

$$Cluster\ Spec_{cr} = \frac{E_{cr}/E_r}{E_{c,CH}/E_{CH}} \tag{3.7}$$

Where $E_{c,r}$ is the employment of cluster c in district r, and $E_{c,CH}$ is the employment of cluster c at the national level. This variable measures the overall strength of the cluster environment in a region; it has a mean of 1.37 and a variance of 0.73.

The fourth explanatory variable is the cluster specialization in a neighboring district. This variable is the average of the variable *cluster spec* of all the adjacent districts. A high average means that the region may benefit from knowledge spillovers, information flows and the proximity of institutions from neighboring regions. Those spillovers and flows may cross the border between two districts and therefore extend the boundaries of a cluster (Delgado *et al.*, 2012, p. 24).

As stated above, due to a lack of data in three-digit classification, we do not consider the fifth explanatory variable reflecting the *related cluster specialization*.

4. Results

The presentation and the explanations of the results will use the structure used by Delgado *et al.* (2012) paper. The first test computes the annualized employment growth rate for each level of industry specialization and cluster specialization (Table IV). The threshold between high and low specialization is determined by the median of each variable, namely, *industry spec* and *cluster spec outside i*. Therefore, all region-industries are split into four groups. As expected, region-industries with lower industry specialization experience greater growth rates, which is consistent with the hypothesis of convergence expressed by the growth theory. The annualized growth rate increases from 2 to 29 per cent when moving to a lower industry specialization (for region-industries with high cluster specialization). The phenomenon of agglomeration forces is also present; region-industries with higher cluster specialization also have a

Explanatory variable(s)		Industry specialization in 2005 Low	 High
Cluster specialization in 2005 outside the industry	Low	$\Delta Employ_{i,r} = 0.15$ $n = 203$	$\Delta Employ_{i,r} = 0.01$ $n = 170$
	High	$\Delta Employ_{i,r} = 0.29$ $n = 170$	$\Delta Employ_{i,r} = 0.02$ $n = 205$

Source: Based on Federal Statistical Office (2015b), Federal Statistical Office (2015b)

Table IV. Annualized employment growth for 2005-2012 by level of specialization (number of observation N = 748) higher employment growth. For region-industries with low industry specialization, the annualized growth rate increases from 15 to 29 per cent when moving from a region with low cluster specialization to high cluster specialization. A control for correlation that may arise among explanatory variables has been realized. The Pearson test and the "variance inflation factor" method have been computerized and have shown that there was no multi-collinearity problem (Appendix 1).

4.1 The "industry growth model"

The second test computes seven different ordinary least squares (OLS) regressions based on the "industry growth model" (equation 3.2) (Table V). The first regression (5-1) tests the convergence effect at the narrowest unit of analysis, the region-industry level. The computed coefficient is negative (−0.130) and statistically significant. This finding means that convergence forces are at work at the region-industry level. Regarding the level of cluster specialization, the expected coefficient should be positive, which would reflect agglomeration forces. In fact, although the coefficient of industry specialization remains negative, the cluster specialization (5-2) has a positive impact on the dependent variable (0.154). In the third regression (5-3), industry and region fixed effects are introduced. Policies or other factors may influence the growth of an industry or a region. However, there are no significant changes to be noticed between regression (5-2) and (5-3). The computed coefficients are of the same magnitude (0.005 percentage point decrease for the industry specialization variable and +0.009 for the cluster specialization variable, respectively). In regression (5-4), cluster specialization in neighboring regions is introduced. The influence of a strong precision engineering cluster in a neighboring region should increase the growth of employment. Thus, the coefficient is expected to be positive; however, it is negative and statistically non-significant. Therefore, it is impossible to draw any conclusions. In the fifth regression (5-5), the industry and region fixed effects are introduced, with no substantial change.

This first model has shown the presence of convergence effects at the narrowest unit of analysis and agglomeration effects at the cluster level in a given district. However, the positive influence of a strong cluster environment in neighboring regions on performance at the region-industry level is not proved to be true when using the precision engineering sector in Switzerland.

After controlling for region and industry fixed effects, it is necessary to test whether a spatial dependency may lead to spatial autocorrelation (Delgado *et al.*, 2012, p. 15). To test for spatial autocorrelation, the Moran's I technique is used. The test follows the same methodology used by Delgado, Porter and Stern but uses another measure. Similar to the original study, the residuals from the regression of the "industry growth model" are used, and an $N \times N$ matrix is computed where $N = 748$ (number of region-industries). The $N \times N$ matrix has elements that take the value one if two region-industries are adjacent and zero otherwise. Using the Moran's I technique, the result shows that the null hypothesis of no spatial autocorrelation cannot be rejected. Therefore, the spatial distribution of the residuals may be completely random (Resbeut, 2015, p. 63).

The importance that a region's size (in terms of employment) can have on agglomeration forces is reflected in Table VI. In fact, the absolute size of a region may influence the externalities and information flows, as well as the economies of scale

Table V. Region-industry employment growth over the period 2005-2012

Industry employment growth					
	Dependent variable: Industry employment growth				
Explanatory variable(s)	(1)	(2)	(3)	(4)	(5)
Ln industry specialization	−0.130*** (0.021)	−0.147*** (0.021)	−0.152*** (0.022)	−0.146*** (0.021)	−0.152*** (0.022)
Ln cluster specialization		0.154*** (0.039)	0.163*** (0.042)	0.156*** (0.043)	0.162*** (0.044)
Ln cluster specialization in neighbors				−0.006 (0.065)	0.009 (0.075)
Observations	748	748	748	748	748
R^2	0.05	0.07	0.091	0.07	0.091
Adjusted R^2	0.048	0.067	0.075	0.066	0.073
Residual std. error	0.751	0.744	0.741	0.744	0.741
F-statistic	38.936***	27.830***	5.627***	18.531***	5.219***

Notes: $*p < 0.1$; $**p < 0.05$; $***p < 0.01$
Sources: Based on Federal Statistical Office (2015b); STATENT (2012)

Table VI.
Region-industry employment growth by size over the period 2005-2012

Industry employment growth by region size		
	Dependent variable: Industry employment growth	
Explanatory variable(s)	(1)	(2)
Ln industry specialization	−0.137*** (0.023)	−0.139*** (0.023)
Ln cluster specialization	0.148*** (0.043)	0.140*** (0.045)
Ln cluster specialization in neighbors		0.037 (0.076)
SIZE × Industry specialization	0.132*** (0.042)	0.138*** (0.043)
SIZE × Cluster specialization	0.044 (0.079)	0.07 (0.091)
SIZE × Cluster specialization in neighbors		−0.061 (0.132)
Observations	748	748
R^2	0.104	0.105
Adjusted R^2	0.086	0.084
Residual std. error	0.736	0.737
F–statistic	5.672***	5.026***

Notes: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$
Sources: Based on Federal Statistical Office (2015b); STATENT (2012)

(Delgado *et al.*, 2014, p. 1793). A dummy variable *SIZE* is introduced and considers the size of each district. The dummy variable equals one when the district has total employment above the median and zero otherwise. An interaction effect is built between the dummy variable and each explanatory variable. The effect of industry specialization on the region's employment takes a positive value and is statistically significant. This means that the larger the region is, the higher the growth rate of employment at the region-industry level. This finding shows that convergence forces in larger districts are weaker than the agglomeration forces induced by the specialization of the industry. The effect of cluster specialization on employment growth in a region registers a coefficient having a positive value that is not statistically significant. This result reflects the fact that the agglomeration effect is greater in a larger region than in a smaller one. This finding is consistent with the view that the larger the region, the greater the externalities and complementarities. As expected, the interaction effect of cluster specialization in neighboring districts is negative because it is stronger in smaller regions than in larger regions (Delgado *et al.*, 2012, p. 30). The table shows that the interaction effect has a negative coefficient; however, it is not statistically significant.

4.2 "Cluster growth model"

The next tests relate to the "cluster growth model". Although the last tables focused on the employment growth at the region-industry level, the following analysis will explain the employment growth at the cluster level for the precision industry, which is a more aggregated level (Table VII). Convergence forces are expected at the cluster-level, depending on the specialization of the district in the cluster. This finding is reflected in all four regressions that show a negative and statistically significant coefficient that is approximately identical (between −0.022 and −0.028). Table VII shows that the cluster environment in neighboring regions has a positive and statistically significant influence on the cluster employment growth (7-1). In regression (7-2), the region fixed effect is

Explanatory variable(s)	Dependent variable: Cluster employment growth (1)	(2)	(3)	(4)
Ln cluster specialization	−0.022* (0.012)	−0.024** (0.012)	−0.023** (0.011)	−0.028** (0.012)
Ln cluster specialization in neighbors	0.055*** (0.016)	0.038** (0.018)		
Dummy high specialization			−0.007 (0.018)	−0.02 (0.019)
Dummy high employment			0.033** (0.017)	0.046** (0.018)
Dummy strong cluster			0.060*** (0.02)	0.057*** (0.021)
Observations	748	748	748	748
R^2	0.015	0.038	0.034	0.063
Adjusted R^2	0.013	0.028	0.028	0.05
Residual std. error	0.186	0.185	0.185	0.182
F-statistic	5.835***	3.658***	6.439***	4.973***

Notes: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$
Sources: Based on Federal Statistical Office (2015a, 2015b data; STATENT (2012)

Table VII. Region-cluster employment growth over the period 2005-2012

added. In the "industry growth model", the cluster specialization did not appear to have any effect at the region-industry level, whereas it has a positive impact when examining a more aggregated level, namely, the region-cluster level. In regression (7-3) and (7-4), the analysis of the cluster environment of neighboring regions is sharpened. Three dummy variables replace the variable *cluster specialization in neighbors* to closely examine the types of environment that may influence the cluster's performance. The result is approximately the same as for the "cluster spec in the neighbors" variable. The dummy variable *high specialization* takes censuses of districts that are adjacent to the top 20 per cent districts, ranked by their LQ value in decreasing order. The dummy variable *high employment* takes a value of one for districts that are adjacent to the top 20 per cent districts, ranked by the absolute employment level. In regression (7-3), the first dummy variable does not play a role. In fact, the coefficient is not statically significant. Conversely, the second dummy variable takes a positive and significant value. In regression (7-4), the region fixed effect is added without any significant change.

Based on these estimations, one can conclude that the relative specialization of a region is not key to increasing the performance of the industry in an adjacent region. It is the absolute size of an industry that positively influences the performance in neighboring regions. This can be explained by the fact that, in Switzerland, there are small districts in absolute size that have high specialization in the cluster, and districts (i.e. cities such as Zurich, Bern or Geneva) that have a small LQ value but a high absolute size. In the first chapter, it was argued that clusters need a sufficient size to enable knowledge spillovers, information flows or to create a sizeable pool of specialized workers.

A third dummy variable measures the influence of a strong cluster environment of neighboring districts on the performance of the industry in the home district. In their paper, Delgado *et al.* (2012, p. 22) identify as strong clusters those that satisfy three cutoffs as follows: the top 20 per cent of specialization (LQ), absolute size and number of establishments. When solely using the LQ approach, the absolute size is not considered, and industries with high specialization but low size in absolute terms attain the threshold. Therefore, a cutoff for absolute size is also introduced. Districts within the top 20 per cent of LQ (*cluster spec*) and absolute size in decreasing order are selected. In accordance with this methodology, 11 districts were selected. This explanatory variable is called the *dummy strong cluster* and takes a value of one for districts that are adjacent to those that have a strong cluster environment. In regression (7-3) and (7-4), the results are striking. In fact, the coefficient is positive and statistically significant, with a value higher than the second dummy variable (0.057). Therefore, districts that are adjacent to others that have a strong cluster environment experience a higher employment growth rate than regions close to districts with a high specialization or a large size in absolute terms. In the "industry growth model", the cluster environment of neighboring regions did not appear to have any effect on the region-industry level. However, it has a positive impact when examining the cluster level.

5. Discussion of the results and limitations of the study

The results have shown that convergence and agglomeration forces also arise in Switzerland for a particular traded cluster, namely, the precision engineering cluster. The region-industry level, as well as the region-cluster level, shows signs of both convergence and agglomeration forces. However, the agglomeration effect that may originate from the cluster environment of neighboring regions does not appear to play any role at the region-industry level. The effect has an influence solely at the region-cluster level. In fact, the variable *cluster specialization in neighbors* takes a positive and significant value in the "cluster growth model". In addition, it was shown that the absolute size of the cluster has more importance than the level of specialization. However, the combination of both high specialization and high absolute size has more influence on the performance of clusters in neighboring regions.

When comparing the results to those from the original study (Delgado *et al.*, 2012), there is one striking difference. Although the effect of convergence and the influence of the cluster environment on employment growth are relatively similar to those found by Delgado, Porter and Stern, there is no influence from neighboring regions at the region-industry level in our study, or at least, the influence is not statistically significant. In the "industry growth model" of the original study, neighboring regions have a positive influence on cluster employment growth (Delgado *et al.*, 2012, pp. 27-28). Concerning the cluster level, the environment of neighboring regions has a positive effect on employment growth, which is similar to the original study. This relation is investigated in greater depth by including three dummy variables. However, this was not tested in the original study.

Another difference between both studies is the importance of the absolute size of each region. In this study, absolute size has no significant effect on the manner in which each variable influences the industry employment growth. In their paper, Delgado *et al.* (2012, pp. 29-30) found clear evidence that the cluster environment has a higher influence on the performance of firms in larger regions. Similarly, the influence of the cluster environment in neighboring regions has a higher impact on the performance of industries in small regions. In this study, no evidence is found to support this. This lack of clear evidence regarding the influence of the size of each district may be the result of the size of the Swiss territory. Although the original study focused on the entire continental territory of the USA, this study solely concentrates on Switzerland, which is very small by comparison. The original study also used EAs as units of spatial analysis, whereas this thesis uses districts. A district in Switzerland is much smaller than an EA in the USA; therefore, the distance between two areas is much larger in the USA. The flows of information and knowledge spillover travel a much shorter distance in Switzerland than in the USA, making adjacent regions less important. However, the presence of a strong cluster environment in an adjacent region remains an important driver of agglomeration effect, although it is in a small country such as Switzerland.

The study has shown weaknesses compared with the original study. Although the lack of clear evidence may be the result of Swiss characteristics, certain enhancements may also increase the probability of having better results. The first improvement that can be made is the inclusion of all traded industries in Switzerland and not solely the precision engineering sector. This improvement makes it possible to use a larger sample that can increase the accuracy of the computed coefficients. However, this enhancement requires further analysis to detect clusters in Switzerland. The accurate aggregation of industries into clusters is of particular importance. In fact, the aggregation of industries that are not closely related to each other will not highlight the agglomeration effects.

Whereas Delgado *et al.* (2014, p. 1789) compute the employment growth over 15 years in their study, our study focuses on a seven-year period due to the unavailability of data over a longer period. Another weakness is also due to the data constraints that force us to rely on a two-digit classification to analyze the effects of the precision engineering cluster on the economic performances of regions.

6. Conclusion

We have defined the boundaries of the precision clusters in Switzerland according to the LQ approach, which has been slightly modified according to the enhancements proposed by Strotebeck, namely, the decomposition of the LQ according to the number of firms and/or the size of firms. We also considered the absolute size of industries. We identified three precision engineering clusters in Switzerland. In a second stage, our study focused on the influence of these clusters on the economic performance of regions where they are located. We applied the methodology developed by Delgado *et al.* in their paper "Clusters, Convergence, and Economic Performance".

The developed models separate convergence and agglomeration forces that are present in different units of analysis, the region-industry level and the cluster level. The empirical analysis shows strong support for the presence of convergence forces at the region-industry level. In contrast, regions with a strong cluster environment experience greater agglomeration forces, resulting in higher employment growth rates. In addition, a region that is surrounded by neighbors with a strong cluster environment also experiences higher agglomeration forces. However, this feature appears solely at the cluster level and not at the region-industry level. The inclusion of three-dummy variables enables us to closely examine which characteristics of the cluster environment in neighboring regions most influence the performance of firms in a given region. The results are striking; the absolute size plays a more important role than the level of specialization in Switzerland. The influence of the so-called "strong clusters" is larger.

These results show that in a small country such as Switzerland, the importance of regions remains. The higher growth rates appear in regions with a strong cluster presence. Although the precision cluster in western Switzerland is driven by the watch-manufacturing industry, the region of central Switzerland benefits from the presence of two larger companies. Complementarities are of particular importance in the cluster theory, and it was shown that regions with the most complementarities across closely related industries experience higher growth rates. Therefore, this result may be significant for economic policies in each of the concerned regions. In fact, policies and grants should focus on closely related industries or those that may have important complementarities with industries that operate within a cluster. This finding may provide insight into the future development of the precision engineering sector in those regions.

Notes

1. To note that LQ does not provide any information regarding the absolute size of a specific industry (Strotebeck, 2010, p. 6).
2. The boundaries of the different regions are drawn by the Federal Statistical Office (2015a).
3. For an exhaustive explanation of the statistic constraints, refer to Resbeut (2015).

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Appendix 1

Explanatory variable(s)	Industry spec	Cluster spec outside i
Industry Spec		
Cluster Spec outside i	0.19***	
Cluster Spec in Neighbors	0.25***	0.48***

Notes: ***Refer to significance levels; all coefficients are here statistically significant at a 1 % level
Sources: Based on Federal Statistical Office (2015b); STATENT (2012)

Table AI. Pearson correlation coefficient of the explanatory variables for the industry growth model

Explanatory variable(s)	Cluster spec	Cluster spec in neigh	High spec	High employ
Cluster Spec				
Cluster Spec in Neigh	0.50***			
High Spec	0.40***	0.68***		
High Employ	0.26***	0.45***	0.37***	
Strong Cluster	0.31***	0.53***	0.61***	0.43***

Notes: ***Refer to significance levels; all coefficients are here statistically significant at a 1 % level
Sources: Based on Federal Statistical Office (2015b); STATENT (2012)

Table AII. Pearson correlation coefficient of the explanatory variables for the cluster growth model

VIF coefficients industry growth model	GVIF	Df	GVIF^(1/(2*Df))
Industry Spec	1.185	1	1.088
Cluster Spec outside i	1.381	1	1.175
Cluster Spec in Neigh	1.778	1	1.334

Sources: Based on Federal Statistical Office (2015b); STATENT (2012)

Table AIII. VIF coefficient of the explanatory variables for the industry growth model

VIF coefficients cluster growth model	GVIF	Df	GVIF^(1/(2*Df))
Cluster Spec	1.448	1	1.203
Cluster Spec in Neighbors	2.939	1	1.714
High Spec	2.612	1	1.616
High Employ	1.567	1	1.252
Strong Cluster	1.903	1	1.379

Sources: Based on Federal Statistical Office (2015b); STATENT (2012)

Table AIV. VIF coefficient of the explanatory variables for the cluster growth model