Productivity Differences between Universities: Are Small and Regional Less Productive?[1]

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Abstract

Are the high number of regional colleges and new universities a burden to the Swedish research system? This question is addressed by analyzing the relationship between input to and output from Swedish higher education units in the period of 2008-2010. Normalization procedures are employed to compare research output between units with different research profiles. Common normalization procedures are used for citations, while a recently presented method—Field Adjusted Production, FAP—is used to adjust publication output with regard to the average publication rate of a Nordic researcher in the different disciplines. Using the FAP method, units are made comparable across different fields and can be measured in terms of productivity and resource efficiency. The aim of the paper is to find out whether there are differences in productivity (output / input) between the regional colleges on the one hand and the universities on the other. The results indicate that cost of producing one unit of research is slightly higher for the regional colleges, but the difference appears to have more to do with the share of competitive grants than university status or unit size. This suggests that, in university research, there are few if any economies of scale.

Introduction

The regionalisation debate in Sweden was started in the 1960's when two new universities were established, in Umeå (northern part of Sweden) and in Linköping. The debate continued and gained momentum during the 1980s and 1990s when university colleges were established in regions all over the country. In the late 1990s, four of these colleges were elevated to the status of university. Today, there are more than 30 universities and university colleges, all with direct resources from the state (floor funding) for research.

This regional development has been criticised from the centre, from the perspective of Stockholm, Uppsala and Lund. Stakeholders claim that the dispersion of resources is detrimental to the research productivity in Sweden and that that the return on investment would be better if resources were allocated to the centre instead of the periphery (Sorlin & Tornqvist, 2000). Concentration of research has been a guiding policy principle ever since the mid 1990s, both in Sweden and in Europe. Whether there are any measurable quality effects of concentration is still an open question; Moed & *al*. (2011) cast serious doubts about this in their study of 40 nations.

Literature overview

Although the literature on research productivity is rich, few studies have really tried to calculate productivity as paper per researcher or similar; in that sense the literature is quite meagre. Referring to reviews by Fox (1983), Toutkoushian & *al*. (2003) and Lee & Bozeman (2005) find

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that most of research interest has focused on the effect of collaboration on productivity. Given the considerable resources that are devoted to publication output, it is surprising that so little attention has been given to institutional-level research output studies. Most studies have kept away from institutional comparisons because of the methodological problems involved. Several of these problems are discussed and accounted for in recent papers by Abramo & *al*. (2011). The Italian group states that although it might be tempting to "simply divide aggregate output values by aggregate input values," such a procedure would be fundamentally and seriously flawed. The reason is quite obvious: a varying intensity of publications and a varying specialization over disciplines between institutions (and countries).

Abramo and his colleagues contend that most of the country studies using bibliometric data fail in this respect (e.g. see the well cited May, 1997; King, 2004). It is well known that medical researchers tend to produce more, often shorter papers where methodology and prior knowledge is codified in citations; and engineering scientists produce less frequently and have fewer cross-references (Narin & Hamilton, 1996). These field differences affect both citation rates and mean number of papers per author, and the differences are to some extent explained by shifting coverage of fields in the ISI database. Not even the methodologically sophisticated scholars Leydesdorff and Wagner (2009), takes the different specialization patterns into consideration when they employ an input-output analysis on the basis of cost per publication and country.

New rankings of universities, as the Shanghai ranking, do not take these differences into account. Also the Leiden ranking (CWTS, 2011) fails on this specific point. Through multiplication of relative citations by number of publications, universities active in the medical areas receive higher rankings, given the same citation performance, due to more frequent publishing.

In an attempt to solve the methodological issue of counting of papers with a normalisation procedure Sandström & Sandström (2009) presented a "field factor for academic production" called Field Adjusted Production (FAP). The FAP factor will be applied in the following analysis of productivity differences between types of Swedish universities.

Input–Research Income

The present study concerns the scientific production in the three-year period 2008-2010. We relate this to the research income for research and research education. The research income figures are mainly based on data from the Swedish National Agency for Higher Education and cover the period 2006-2008 as we expect that there is a certain lag in publishing activities. In addition to the National Agency's statistics, data from the Swedish Statistics and other sources are employed in order to estimate the financing of research at university hospitals.

Universities and university colleges are categorized according to their actual funding structure, and how the research income is composed (see Appendix B). While some of the regional colleges have a low share of competitive grants (≈ 30%) and mainly on rely government appropriations, other regional universities have a high proportion (40-50%) of competitive grants. The new universities are, as a category, largely dependent on direct government funding and have a low proportion of competitive grants. Technical universities with their engineering faculties are very much dependent on competitive grants. The large universities, with activities across several faculties, typically have a lower proportion of competitive grants. This is the basis for the classification of our units of higher education (HE Type):

- Low = six regional university colleges with low proportion of competitive grants,
- High = five regional university colleges with high percentage of competitive grants,
- Newu= four new universities, with a low percentage of competitive grants
- Spec = two major technical universities, with a high proportion of competitive grants
- Univ = six large universities with several faculties and extensive scientific operations, and low percentage of competitive grants.

It should be noted that Karolinska Institute, as well as the Swedish University for Agricultural Science (SLU), the Swedish School of Economics (HHS) and Lulea Technical University (LTU), are not included in the study. Consequently, we can use our analysis for a tentative test of the following hypothesis: a high proportion of competitive grants will lead to higher productivity and better quality of research.

The question of which types of research income to consider in an investigation of this kind is open for discussion. Annex 2 provides an account of universities' revenue for research and postgraduate training, broken down by income category and by type of institution. The amount of external resources and the appropriations are also provided. How shall we treat "fee revenues" related to research? Should they be included in this discussion about efficiency from the output point of view? And what about the contract research category; should such money be considered as input that contribute to publication output? When comparing between university categories, most differences between income categories are quite marginal. The main difference is the proportion of the contributions (and the proportion of funding) directly from the state as appropriations or direct funding (floor funding). For this reason, all types of income for research and research training are taken into consideration in the following analysis. This means that all income, regardless of where the money comes from, is deemed to contribute to the publishing activities. Consequently, we assume that universities can use most of the extra inputs for research and that they are able to translate all money into publications. While this is not always possible, it is likely that the bulk of the funds have such a function. Furthermore, even if the contract research and fee revenues are removed from total revenues, the results will change significantly from the results presented herein.

Table 1 provides the basic information on the distribution of research income between university categories. Competitive funding schemes are an essential part of most university's research income. The percentage of competitive funding is the basis for our "test" of the hypothesis that competitive grants are driving productivity and quality of research. Column "STDV" in Table 1 shows the standard deviation of the contribution of the respective categories measured in percentages. For the selected set of universities and colleges, the material in each category turns out to be relatively uniform. Data is shown in Table 1.

Table 1. Grants and Total Income 2008-2010 (million SEK).

Type	Competitive Grants	Total income	Yearly Income	Cumu-lative	Share Grants	Stdv
high	757	1 566	522,2	2,7%	48,3%	4,6%
low	556	1 701	567,2	5,6%	32,7%	4,2%
newu	1 036	3 556	1 185,5	11,7%	29,1%	2,4%
spec	5 239	9 836	3 278,6	28,5%	53,3%	2,4%
univ	17 610	47 467	15 822,3	100,0%	37,1%	4,6%
Totalt	**23 081**	**58 433**	**21 376**		39,5%	

Note: Figures in SEK. Source: Swedish National Agency for Higher Education, Sweden Statistics and county statistics.

Table 2 has been adjusted to include the county council's research contributions into the statistics. County councils and other R&D organizations work at the boundary between university hospitals and universities. Obviously, the boundary is permeable and this creates problems when we work with the unification of institutional addresses. In addition, many researchers are employed both by the university and the hospital. There is a growing tendency to use the university address instead of hospital or county address. If we include the county council funding, this situation will be less problematic.

Unified institutional names

Cleaning of data is onerous task, partly due to sloppiness, partly due to the number of organizations at the boundary of many universities. This might create dubious allocation of articles (Debackere & Glänzel, 2004). We have been working with this aspect since 2004 and have developed a combination of automatic and manual procedures for unification of addresses. The current study applies the universities organization as of October 2011 implying that research institutes that were merged with a university in early 2011 will count as part of the university for the whole period of 2008-2010.

Output–Field Adjusted Production

An analysis of universities resource efficiency will have to face the problem of finding a method for comparing output across different fields of research. If not, a university that exclusively focuses on medical research will tend to get exaggerated results, while the result of a university with mixed operations, including humanities and social sciences, will tend to be understated. In the former case, the number of publications will expectedly be higher compared to a university of the same size heavily involved in humanities and social science research.

To account for differences in publication rate between fields, one could adjust the publication output with regard to the average publication rate of a researcher in each field. In order to solve this problem we have to turn to the more theoretical side of bibliometrics where interesting starting points have been provided in the discussion on publication productivity.

Most of the discussion on publication productivity has been framed within discussions on the feature of frequency distributions (Braun, Glänzel & Schubert, 1990). The focus here is

especially put on the Waring distribution, originally introduced by H.A. Simon (1955) as a generalization of the Yule distribution and further analyzed by J.O. Irwin in (1963), as the most reasonable way of accounting for publication productivity processes. As the number of all authors (including authors with zero publications) is not known, the distributions are zero-truncated. Seeking for actual authors would require detailed data concerning the entire researcher population. Another option would be to use statistical estimates based. This was done in Koski, Sandström & Sandström (2011, abbreviated KSS 2011), the result of which indicate that it is possible to estimate the number of potential authors in a productivity distribution (i.e. the zero-class of the publication frequency distribution). This enables the creation of more advanced productivity measures.

The aim of this paper is not to take these methodological issues further—the reader can find the basis for our procedures in the KSS 2011 paper—but to use the productivity measures on an empirical data set. Before we proceed, the steps taken to establish the reference values used to compare between fields will be outlined. Although the scope of the method is quite demanding we can summarize it in the following steps: 1) create a set of Nordic papers where the names of the authors are disambiguated with the use of cluster procedures à la Soler (2006); 2) create journals cluster using the "Louvain method" (Blondel & *al*., 2008) on the basis of journal to journal inter-citations (Boyack & Klavans, 2006), which returned 22 clusters; 3) calculate reference values per area using the methodology set out in KSS 2011.

Disambiguating author names is an essential part of the FAP method since it is based on publications per author. The method for this is inspired by Soler (2007) and further developed in discussions with Peter van den Besselaar and his team (Guerney et al. forthcoming). The disambiguation of author names was performed with an algorithm that employs all relevant categories of information in the Web of Science—addresses, citations, co-authors, journals, abstracts etc. —in order to separate distinct authors.

We claim that the FAP-method makes possible comparisons over areas of science. While social sciences have low reference values, physics and chemistry have high (corresponding to the publication rate of a "normal" Nordic researcher). Accordingly, using the reference values we can weigh the publication output to create a field adjusted (normalized) output values. This is the Field Adjusted Production (FAP) figure.

In this study there is also considered a quality component. While bibliometrics have many advantages one of the most obvious weaknesses is that the publications need time to collect citations. For this reason, the study has used citation data relating to publications in the period of 2004-2007, counting citations from publications in Web of Science up to 2011.

Findings

We now proceed to the actual investigation analyzing productivity per category of Swedish higher education units. We have five different categories, which are structured in two dimensions: size of operations and share of competitive grants. Table 2 shows number of publications and Field Adjusted Production (FAP) per category. When output is related to input (research income) we can establish a unit cost or a productivity measure as publications per million SEK.

Table 2. Number of publications (P), sum of publication fractions (Frac P), field adjusted publications (FAP), yearly income and unit cost per types of HE institutions, 2008-2010.

HE Type	P	Frac P	FAP	Yearly Income MSEK	Unit cost MSEK	FAP/ MSEK
high	1 061	498,6	733	522	0,712	1,40
low	1 277	600,0	863	567	0,657	1,52
newu	2 301	1 163,7	1 698	1 185	0,698	1,43
spec	7 737	4 132,8	4 626	3 279	0,709	1,41
univ	40 023	19 612,6	25 222	15 822	0,627	1,59
Totalt	**52 399**	**26 007,8**	**33 142**	**21 376**	**0,645**	**1,55**

Note: Web of Science, NU database (HSV), Statistics Sweden.

The results reveal that there are differences in productivity, but these differences do not run on the lines that have been assumed by actors in the discussion mentioned above. There seem to be three distinct groups with somewhat different working conditions. First, smaller shares of competitive grants (low and univ) seem to be drivers of productivity. Second, higher shares of competitive grants (spec and high) seem to imply higher cost per unit. New universities with a relatively low share of competitive grants break this pattern and exhibit high unit costs.

Special universities (technical) have the same unit cost as the group of technically oriented, regional colleges (high) and universities have about the same cost as the more social science-oriented regional colleges. Regarding productivity, we cannot talk about differences between on the one hand universities and on the other hand regional colleges. Instead, we might think in the direction that some types of research are more costly to perform or that operation of competitive grants might be detrimental to productivity. We will come back to this discussion.

We are yet to show straight output (P or Frac P) in relation to input. It is quite interesting to dwell upon the figures. In Table 3 we show indexed figures, compared to the category "univ," for three indicators of productivity: publications, fractional publications and FAP. Consequently, Table 3 exposes the effect of the FAP procedure. Differences that can be traced back to how topics of research are distributed over categories are evened out when the FAP method is applied.

Table 3. Comparing three measures of productivity.

	P/ Income	Frac P/ Income	FAP/ Income
high	0,80	0,77	0,88
low	0,89	0,85	0,95
newu	0,77	0,79	0,90
spec	0,93	1,02	0,89
univ	1	1	1

Citation "productivity"

We have shown that the small regional colleges are about as productive as the "big" universities, but what about the quality of "regional" research compared with university performances? Since there are no variable that directly measures quality of research we have to be content with a proxy that is relatively accepted in most research circles—citations. We use the period 2004-2007, a four year period, with a relatively long citation windows, citations until 2011. It gives a result which should reflect the actual conditions without the influence of delays and should provide us with significant citation values. But, whether these will be representative for the later period is, of course, an open question.

What are our expectations? It is reasonable that regional universities have a lower normalized citation rate, compared to the larger and more established universities and technical universities. Regional colleges and the new universities were established as recently as about 15 years ago. Therefore, there are reasons to expect lower citation rates from the smaller units. At the same time it is likely that there are research groups that have moved from universities to the regional colleges, and these groups would be able to perform relatively well if given a nurturing environment and relevant support for their research activities.

Table 4. Citation indicators per category.

Typ	P	Frac P	NJCS	NCSf	SCSf
high	801	421,3	0,88	0,86	-0,01
low	1195	608,2	0,91	0,85	-0,05
newu	2754	1475,3	0,94	0,93	0,05
spec	10688	6286,3	1,10	1,02	0,11
univ	41279	25217,5	1,10	1,11	0,16

Note: Indicators are further defined in Appendix 1.

The first two columns, P and Frac P (fractions) give the order of magnitude. As each category contains several units of operation the "high" and "low" are really small compared to the "ordinary" universities. The impact indicator NJCS expresses the normalized journal citation score, i.e. quality of the journal in which units have been published. Clearly, new units (regional colleges and new universities) have a preponderant part of their articles in lower impact journals. There are considerable differences in this respect but the indicator may be said to indicate potential, not actual, quality. This latter is reflected in the field normalized citation indicator (NCSf) which exhibits rather marked differences between HE types. In relative terms regional colleges are more than 20 % lower in the citation scores (e.g. NCSf). The new universities are somewhat better performing than colleges, but differences are probably far from significant.

The SCSf indicator (McAllister & *al*., 1983) takes away some of the edginess that characterizes an indicator based on averages for a data set that is extremely skewed in the citations distributions (see further explanation in Appendix 1). Differences remain even if the regional colleges and new universities are somewhat closer to the global expected number of citations (= 0).

Non-parametric measures have certain advantages as they do not require the production of reference values (Rousseau, 2005; Leydesdorff & Bornmann, 2011) Considering the difficulties

with reference values, it is therefore of great interest to use percentiles of citations (per subject category). TOP1% shows the percentage of articles that match the criteria to be within the 99th percentile, and likewise as we work with 5%, 10%, 25% and 50%.

The TOP1% indicator highlights differences between entities, but is of course also dependent on how many there are that are active at the international publication market. Interestingly, the regional colleges with low proportion of competitive grants are very close to the broad and large universities. But, this is changed the further down the line we get and when at the 25 or 50 per cent level the differences are again quite substantial.

Essentially, the non-parametric indicators give the same picture as the one emerging from the "mainstream" parametric indicators. The regional universities are generally about 15-20 % less "productive" compared with the performance of the universities.

Table 5. Non-parametric indicators based on percentiles.

Type	TOP1	TOP5	TOP10	TOP25	TOP50
high	0,8%	3,6%	7,7%	22,7%	51,9%
low	1,0%	3,5%	7,6%	21,7%	48,8%
newu	0,6%	4,3%	8,7%	23,9%	54,7%
spec	0,7%	4,5%	9,9%	27,8%	58,0%
univ	1,0%	5,6%	11,6%	30,2%	59,1%

These percentile values and other indicators can be based on FAP-weighted publications and such control has been implemented. However, even if results differ to some small extent they are not significantly different from those shown in Table 4 and 5. Irrespective of that we will use weighted factors in the next paragraph where we combine production and citations into a composite indicator.

A Composite Indicator for University Performance

What society receives from research investments is of course a larger issue than can be answered by publication statistics. At best, a comprehensive measure can be developed that approaches the goal of combining production and quality. The FAP-weighted production gives a realistic picture of levels of activity and if we add citations we possibly can develop a measure of resource efficiency at Swedish universities and university colleges.

All citation indicators seem to indicate synonymous differences between colleges and universities. The NCSf indicator has been criticized because it uses averages of data that are often utterly skewed in their distribution. Instead, we propose the use of SCSf which measures the standard deviation from the global mean (= 0) and takes the log of citations; a procedure that compresses the values in the direction of the median, please note that when using SCSf we have added 1.0 to the actual figure.

Table 6. Composite Indicator (efficiency) per HE type (2008-2010).

Column	1	2	3	4	5
Typ	FAP	SCS (SCSf+1,0)	FAP* SCS	Yearly Income MSEK	Efficiency Col3/ Col4
high	733	0,99	728	522	1,394
low	863	0,96	828	567	1,459
newu	1 698	1,05	1 783	1 185	1,504
spec	4 626	1,11	5 131	3 279	1,565
univ	25 222	1,17	29 613	15 822	1,872
Total	**33 142**	**1,14**	**38 083**	**21 376**	**1,782**

Note: SCSf based on papers 2004-2007.

Results are given in Table 6 and are based on FAP-weighted production during 2008-2010 multiplied by the SCSf indicator which builds on publications from 2004-2007. This provides a measure of resource use efficiency provides a summarizing measure of research performance: Universities are by far the most efficient in its use of resources. The technical universities and new universities are at the same level. Just below these are in turn the regional colleges and differences in that group is diminishing when citations are put into the picture. The discrepancy between broad and established universities on one side and the new regional colleges on the other is about 20 percent, a substantial difference.

Discussion

In simple terms the question for this study is formulated: Are the regional university colleges a burden on the Swedish research system? The paper shows that this is not the case, but concerning quality issues there is still a way to go for the regional university colleges. No doubt, still there is fuel for further discussion, but discussions should start from real and not alleged differences between university colleges and established universities.

The paper addresses an issue that has been debated for long time by analyzing the research output in 2008-2010. Using a weighting procedure for production from different fields of research, the units are made comparable in terms of productivity and resource efficiency. Of course, several parameters have to be taken into account, if we want a realistic way to indicate societal impact of research, but this particular paper is limited to studying the relationship between output in the form of publications and input in the form of revenue for research.

From various methodological approaches we have examined whether there are differences in productivity (output / input) between groups of regional university colleges and groups of universities. The cost for producing one unit of research (corresponding to a Nordic standard researcher output) is slightly higher for the regional university colleges, but the differences seem to emanate more from the share of competitive grants than the university status and size of operations.

If the regional universities' resources were transferred to the universities, we would annually win just under ninety normal researchers' production, which translates to a figure of ten new researchers for each large university. This is what the regionalisation debate is all about when we boil it down to its core.

Overall, the regional universities are about as productive as other sectors of higher education institutions. While the differences in the article production are small, almost negligible, the differences in citation rates are larger. At the end of the day, if the regional universities are to escape the epithet "burden" to the system, it is necessary to formulate strategies for improving the quality of research.

The second test, are universities with a high proportion of competitive grants more productive than universities with a lower proportion, indicates that this is not the case. Competitive funds are associated with lower productivity. We will discuss this further and relate to theoretical notions concerning the conditions for university research and how funding schemes might affect research (e.g. Heinze, 2008) in the full paper.

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Appendix 1 Indicators used in the paper

P — Number of papers. Papers (articles, letters, proceeding papers and reviews) during 2008–2010.

Frac P — Number of fractionalized papers. Sum of author fractionalized papers (articles, letters, proceeding papers and reviews) published during 2008–2010.

FAP — Field Adjusted Production. The number fractionalized publications adjusted with regard to the average publication rate of a Nordic researcher within the relevant fields.

NJCS — Normalized journal citation score. Denotes impact of the journal set normalized in relation to its sub-fields (average=1.00). When calculating the "Normalized journal citation score" we use the following formula:

$$\frac{1}{P}\sum_{i=1}^{P}\frac{[\mu_j]_i}{[\mu_f]_i}$$

where $[\mu_j]_i$ is the average number of citations received by papers in the journal of paper *i* and $[\mu_f]_i$ is the average number of citations received by papers in the sub-field of paper *i*.

NCSf — Field Normalized Citation score. The former explanation (NJCS) applies also to this indicator.

SCSf — Standard field citation score (average=0). Z-score standardized citation score in relation to the sub-field set. SCS is the main indicator used in this paper and defined as follows:

$$\sum_{i=1}^{P}\frac{ln(c+0,5)-[\mu_{f[ln]}]_i}{[\sigma_{f[ln]}]_i}$$

where $[\mu_{f[ln]}]_i$ is the average value of the logarithmic number of citations (plus 0.5) in the normalization group and $[\sigma_{f[ln]}]_i$ is the standard deviation of the $[\mu_{f[ln]}]_i$ distribution (based on McAllister, PR, Narin, F, Corrigan, JG. 1983).

TOPx% — Percentage of papers above the chosen (99^{th}, 95^{th}, 90^{th} etc.) citation percentile.

Appendix 2 Revenue Structure for Swedish universities and university colleges

Table A. Revenue structure in 2006-2008, all income (thousand SEK) for research and postgraduate education.

Type	Fees	Grants	Financial	Commissioned	Direct appropr	Other approp	Total
high	42 462	756 518	14 967	141 666	311 620	299 247	1 566 480
low	64 214	556 013	8 134	69 018	467 945	536 145	1 701 469
newu	72 418	1 035 837	44 798	192 919	2 210 521	0	3 556 493
spec	369 076	5 238 662	152 884	660 684	3 414 430		9 835 736
univ	2 149 406	15 494 428	527 338	2 491 928	17 645 893	3 463 922	41 772 915
Total	**2 697 576**	**23 081 458**	**748 121**	**3 556 215**	**24 050 409**	**4 299 314**	**58 433 093**

Table B. Revenue structure in 2006-2008 for research and postgraduate education in percentages.

Type	Fees	Grants	Financial	Commissioned	Direct appropr	Other approp	Total
high	2,7%	48,3%	1,0%	9,0%	19,9%	19,1%	100%
low	3,8%	32,7%	0,5%	4,1%	27,5%	31,5%	100%
newu	2,0%	29,1%	1,3%	5,4%	62,2%	0,0%	100%
spec	3,8%	53,3%	1,6%	6,7%	34,7%	0,0%	100%
univ	5,1%	37,1%	1,3%	6,0%	42,2%	8,3%	100%
Totalt	**4,6%**	**39,5%**	**1,3%**	**6,1%**	**41,2%**	**7,4%**	**100%**

Table C. Income distribution in external funding and grants funds per type of university, thousand SEK and per cent (%).

Type	External	Internal	Total	Type	%_External	%_Internal	Total
high	940 646	625 834	1 566 480	high	60,0%	40,0%	100%
low	689 245	1 012 224	1 701 469	low	40,5%	59,5%	100%
newu	1 301 174	2 255 319	3 556 493	newu	36,6%	63,4%	100%
spec	6 268 422	3 567 314	9 835 736	spec	63,7%	36,3%	100%
univ	20 135 762	21 637 153	41 772 915	univ	48,2%	51,8%	100%
Totalt	**29 335 249**	**29 097 844**	**58 433 093**	**Totalt**	**50,2%**	**49,8%**	**100%**