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The Determinants of Research Production by U.S. Universities

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Abstract

In this paper, we analyze the determinants of the production of research by higher education institutions in the U.S.. We use the information contained in the Shanghai ranking to estimate their performance in the production of top level academic research. We show that it is important to account for the presence of outliers, in both dimensions (x and y axes), among institutions. It appears that most of the top ranked institutions must be considered as outliers. We also treat the endogeneity issue and test for the possible selection bias. We find that the income, the share of this income devoted to expenses in research and the number of professors very significantly increase the ability of an institution to produce top level academic research. We also show that the relationship between the average quality (salary) of professors and the production of research is U-shaped with a significant share of institutions located on the decreasing part of the curve.

JEL codes I23, I2, H52, C21

1 Introduction

Economists usually consider higher education institutions as firms: they need inputs to produce outputs. In a special issue of the Journal of Economic Perspectives (1999), Clotfelter considers that "[...] the higher education industry [is] composed of some 3,600 'firms' of vastly different sizes and missions". Winston (1999) goes even further: "Higher education is a business: it produces and sells educational services to customers for a price and buy inputs [...]". Even if higher education institutions must produce educated students, they have another important mission: to produce research.

The aim of this paper is to identify, for the U.S. institutions that produce research, the determinants of the production of academic research. The identification of the leverages which allow the institutions to increase their research production is important because it relates to the following three fundamental questions:

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First, how can the public investment in universities be optimized? More generally, this question relates to the optimal strategy to improve the production of top level academic research. A significant share of R&D investments made by governments is directed toward universities. In order to improve the effectiveness of the use of public funds, we must identify the effect of revenue in various universities: should the best universities be privileged? Should governement improve research funds of universities belonging to the lower part of the distribution? It is also important to identify the leverages through which a university might improve its research production. For instance, for a given level of salary expenditures, should the quantity or the quality of the hired professors be improved (more professors with lower wages vs. less professors with higher wages)? Furthermore, for a given university revenue, how should expenses be allocated between education and research, "hard" and "soft" sciences, etc. These questions relate to the optimal allocation of ressources to improve the production of research.

From another perspective, Hazelkorn (2008) estimates that "Institutions believe that high rankings can boost their 'competitive position in relationship to government'. In turn, government and funding agencies are more favourably disposed to highly ranked Higher Education Institutions". Therefore, universities should learn to live with rankings and try to appear in a good position in order to maintain or increase their financial support.

Second, how can the growth of a country be improved by the presence of universities? Economists consider human capital, innovation and more generally, R&D as the main source of growth for a country. The role of the public sector in R&D funding and the optimal relationship between fundamental and applied research are not clear[1]. There is a general consensus on the fact that fundamental research must be subsidized, otherwise it would be under-funded and this could affect growth.

Third, since parts of public investments in higher education is increasingly related to institutions' performances in research production, how can we identify the characteristics which improve their performances? In turn, increased performances are likely to help universities to increase their public funding at the expense of their competitors.

The number of rankings for higher education institutions has dramatically increased over the last few years. We should distinguish international from national rankings proposed in some countries (i.e. the "U.S. News Ranking" in the US, the "Innovation Indicator for Germany",

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[1] This is particularly true for the academic sector.

etc.). International rankings generally compare institutions working in very different environments. Two of them deserve particular attention because of their diffusion. On the one hand, the Times Higher Education Supplement (THES) ranks institutions aggregating both the education and the research they produce. It uses several indicators such as the students/professors ratio, the number of foreign students, peer review for research, etc. On the other hand, the "Academic Ranking of World Universities" (ARWU), proposed by the Shanghai Jiao Tong University, assesses the production of scientific research. The information contained in this ranking will be used to evaluate the research production in universities and we will present it more carefully in the third section of this paper.

To identify the determinants of the production of research, we use a database collecting informations on different characteristics of the U.S. universities. The estimation strategy is quite complex. We have to deal with endogeneity issues as well as with the presence outliers. Furthermore, we test the robustness of the presented results by testing for a possible selection bias (we only have access to the measure of the production of research for institutions present in the Shanghai ranking) and we use quantile regressions to check wether institutions belonging to different part of the distribution behave differently. Finaly, our final test consist of performing seemingly unrelated regressions on different measures of the production of research instead of using our aggregated index.

It is important to keep in mind that universities usually have three different missions: education, research and services to the community. In general, rankings are not able to assess these different missions simultaneously. At best, they can partially compare the ability of the institutions to reach some of their goals. Furthermore, even if the mission of education is - at least - as important as the production of research, rankings generally focus on the latter. Or focus on U.S. universities has the advantage of avoiding several difficulties commonly encountered in international comparisons of institutions. There is no language bias, the environment is much more homogenous, in particular universities face the same federal legislation, their goals and missions are similar and they compete for the same research funds. Nevertheless, some disparities subsist between States and we will have to take this into account.

The paper is organized as follows: in the next section, we present the database which is used. We present and discuss the Shanghai Ranking (the information of which is used as our dependent variable) in section 3. Section 4 is devoted to the empirics of the paper. We start by presenting simple OLS regressions aiming to identify the determinants of the production of research and account for endogeneity by using instrumental variable estimations. We then investigate the importance of the presence of outliers among universities by running robust estimations. As it will be shown, the detection and identification of several types of outliers is informative. Finally, we investigate the possibility that the different institutions behave differently according to their place in the distribution by using quantile regressions. Section 5 is devoted to a sensitivity analysis and we conclude in Section 5.

2 The database

To carry out this research, we have built an original database on the basis of two different sources. First, "The Integrated Postsecondary Education Data System" (IPEDS) is a data collection managed by the National Center for Education and Statistics (NCES). Since 1985, every post-secondary institution must report annually information on a wide range of topics, varying from the composition of the student population to the salary expenses for different categories of employees. We extracted information on every institution from the database about their type, the characteristics of their student population, their employees, their sources of revenue and their expenses. Second, we use the "Academic Ranking of World Universities", available from 2003 on, which provides the ranking of 510 universities around the world, 164 of which were located in the U.S. in 2007. We propose a deeper analysis of this ranking in the next section.

Further on, we use the Shanghai ranking published in 2007, based upon the universities' characteristics in 2005. Looking at the descriptive statistics, it is important to note that there are huge disparities between institutions. The number of students of the institutions present in the ranking goes from 200 to 50,000; on average, public universities are much bigger than the private ones, etc. Among the 4239 institutions present in our database, around 15% propose a Ph.D. degree and less than 4% are present in the Shanghai ranking. When testing for the presence of a selection bias, we will restrict our sample to institutions whose research spending is higher than 2% of their revenue and which deliver Ph.Ds. This embodies 378 institutions, including the 164 ones that are present in the ranking. The descriptive statistics for these two sub samples are presented in Table 1 in the appendix.

3 The Shanghai Ranking

This ranking was first published in 2003. It aimed to help the Chinese authorities to measure the distance between Chinese universities and the institutions identified as world leaders. Therefore, its goal was to define the quality of higher education institutions, aggregating all of their activities. Looking at this ranking's criteria, it obviously focuses on the research produced by universities.

The aim of this section is to present the Shanghai ranking and explain why it is a good measure of the production of a particular kind of research: top level academic research, mainly fundamental research. We will start by presenting the criteria on which the ranking is based, then we will briefly discuss its strengths and weaknesses. From the information contained in the ranking, we will build a measure of the production of research by the higher education institutions in the US.

3.1 The Shanghai criteria

The Shanghai Jiao Tong University in charge of the ranking uses six criteria. Four of them measure, by different means, the top level research produced by the institutions. For every criterion, the scores of all institutions are normalized relatively to the best institution which receives a score of 100.

The criteria are:

- *Alumni*: Alumni of an institution who won Nobel Prizes and Fields Medals.
- *Award:* Staff of an institution who won Nobel Prizes and Fields Medals.[2]
- *HiCi:* Highly cited researchers in 21 broad subject categories (life sciences, medicine, physical sciences, engineering and social sciences).
- *N&S:* The number of articles published in "Nature" and "Science" during the last five years.

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[2] The ranking takes into consideration the Nobel prizes in physics, chemistry, physiology or medicine and economics. Fields Medal are awarded every four years to 2, 3 or 4 mathematicians who are under the age of 40. Staff is defined as those who work at an institution at the time of winning the prize. Different weights are set according to the periods when winning the prizes. The weight is 100% for winners in 2001-2003, 90% for winners in 1991-2000, 80% for winners in 1981-1990, 70% for winners in 1971-1980, and so on, and finally 10% for winners between 1911 and 1920. If a winner is affiliated to more than one institution, each institution is assigned a weight equal to the inverse of the number of institutions. For Nobel prizes, if a prize is shared by more than one person, weights are set for winners according to their proportion of the prize.

- *SCI:* The total number of articles indexed in the "Sciences Citation Index-expanded" and in the "Social Sciences Citation Index" during the previous year.
- *Size:* The weighted score of the five mentioned indicators normalized by the number of full time equivalent academic staff.

On the basis of these six criteria, the score for the Shanghai Ranking is given by the following formula:

$$Shanghai\_score = .1 * alumni + .2 * award + .2 * HiCi + .2 * N\&S + .2 * SCI + .1 * Size \quad (1)$$

Table 2, in the appendix, presents the correlation coefficients between the criteria used for the ranking.

3.2 Strengths and weaknesses of the Shanghai ranking

Chang and Liu ("WCU I") have listed the methodological problems encountered for this ranking. Firstly, the criteria which are used focus on a particular kind of research; more than 80% of the score concerns top level academic oriented research and only a share of 10% of the score is linked to the mission of education (*alumni*) while 10% is related to the efficiency of the staff (*Size*). In order to present a coherent analysis, we will exclude these two last criteria from the analysis and rather concentrate exclusively on the mission of research. Secondly, the criteria favor "hard" sciences oriented institutions as at least three of the four remaining criteria are measures which are mainly oriented towards hard sciences.[3] We must take this fact into consideration and control for the relative focus of institutions on "hard" versus "soft" sciences in our regressions. Thirdly, it is not clear whether the ranking aims to assess the production or the efficiency in producing research. To avoid any confusion, as said before, we will exclude the measure of efficiency (criterion "*size*") from the analysis. Fourthly, the choice of weights does not respond to an explicit strategy for the computation of the score for the ranking. It is therefore important to assume that the weights which have been used for the computation of the score may be different. We will use an alternative measure of the score based on a Principal Components

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[3] Only 10 to 20% of the Highly Cited Researchers work in "soft" sciences orientations, whereas almost all authors who publish in Nature or Science work in hard science fields and among the awards being taken into consideration in the ranking, the majority concerns "hard" sciences.

Analysis (PCA) of the four criteria used for our analysis. We will show in the next section that the correlation coefficient between this measure and the score of Shanghai is higher than 99%.

3.3 The use of the Shanghai ranking in the analysis

It is important to note that we use the underlying score for each criterion as opposed to the "rank" of the institutions because it presents the advantage of being continuous and set between 0 and 100 for each criterion. Bearing in mind the main criticisms addressed above, we propose three different measures of the production of research by universities. They are all based on the information contained in the Shanghai ranking.

1. The use of the "Shanghai score" whose computation is presented in equation (1). As said before, this measure presents several shortcomings: the weights are arbitrarily chosen and it contains heterogenous information (aggregating measures of production and efficiency and measures of research and educational activities). Therefore, we will use this measure to check the robustness of our results.

2. We will continue to stick to the Shanghai ranking, but purify the measure from the noise due to the inclusion of the criteria *size* and *alumni* in order to keep the information related to the production of research only. This measure is obtained by the following formula:

$$shanghai\_prod = \frac{2*award + 2*HiCi + 2*N\&S + 2*SCI}{8} \tag{2}$$

3. A last strategy to build a variable that should be a good measure of the research produced by universities is to perform a principal component analysis (PCA) of the four dimensions measuring the production of research in the Shanghai ranking. We call this variable *shanghai_pca*. It should be noted that the first component captures more than 84% of the variance of the four criteria. This suggests that the four criteria can adequately be summarized in only one measure.[4] The reason why we only retain this measure to check the robustness of our results is due to the fact that the weights would change every year, making comparisons across time impossible.

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[4] Dehon *et al.* (2009) have shown that if we use a robust principal component analysis on the criteria of Shanghai, we observe that the criterion *Award* behaves quite differently from the three others used in this paper. At the end of the paper, we check the robustness of our results and show that a Seemingly Unrrelated Estimations using the four criteria yields essentially the same results.

The correlation coefficients between these three variables (*shanghai_score*, *shanghai_prod* and *shanghai_pca*) and the six criteria of the Shanghai ranking are presented in Table 2. Remember that our main analysis will focus on the *shanghai_prod* measure. This choice is related to the ability of these criteria to measure a particular kind of research, i.e. top level academic research, mainly for *Award*, *HiCi* and *N&S* while the fourth criterion captures the academic impact of the produced research.

4 The econometrics

In this section we will look at the characteristics of the institutions that are present in the ranking and which may favor the improvement of their performances in the production of research. We start by presenting OLS and 2-SLS estimations where we instrument the revenue of institutions. We present the Huber-White standard errors that are robust to the presence of heteroskedasticity. Then, we propose to go further in the analysis using robust estimations that allow the identification of several types of outliers. As it is shown, the "bad outliers" are to be found among the top ranked institutions. Therefore, we run some weighted OLS estimations where we give a weight of zero to these "bad" outliers and a weight of 1 to the other observations. This procedure ensures that the presented results are not driven only by the best institutions. Finally, we run weighted 2-SLS estimations to control for the endogeneity issue. Another strategy to understand the presence of these top institutions among the bad outliers consist to run quantile regressions to check wether universities belonging to different part of the distribution behave differently. The main results are discussed and we treat some additional issues such as selection bias in a final section.

4.1 OLS and endogeneity issue

We estimate the following equation:

$$shang\_prod2007_i = \beta_1 X_i + geog\_control_i + \varepsilon_i \tag{3}$$

where X_i contains the characteristics of university i: the logarithm of the total revenue in millions of US$, the number of full time professors, the number of full time assistant and associate professors, the share of the revenue spent on research activities, the proportion of students in hard sciences fields (as a proxy for the specialization of the institution), the average salary of the professors and the square of this variable. Furthermore, for each regression, we run a second regression with another control variable: a dummy for the State in which the university is located. We believe that it might be important to control for the State of location for several reasons: first of all, in a very competitive environment, higher education workers (professors, etc.) are much more mobile than in Europe (see Wasmer (2006) for the mobility of workers in Europe and in the US). Furthermore, the ability for an institution to attract the best professors is likely to be affected by the environment (the climate, e.g.). Also, the organization of higher education is the responsibility of the State, not of the Federal State. Disparities between States are thus likely to appear. This second idea is confirmed by Aghion et al. (2007). They estimate that "States vary not only in the relative importance of private versus public universities, but also in the degree of autonomy granted by State authorities to public universities". We will come back to this statement later.

The first two columns of Table 3 contain the standard OLS estimations for all of the institutions present in the ranking. But, as mentioned before, there is an increasing tendency to link public funding to performances. It is therefore reasonable to be concerned by the endogeneity issue and we run some instrumental variable estimations.

We believe that the main potential source of endogeneity concerns the revenue of institutions. The other explanatory variables are not expected to be endogenous: the allocation of resources (for research), the number of hired professors, their quality (salaries), etc... are expected to be independent from the ranking of the institution. At least, we believe that if there is a link going from the performances in the production of research to these variables, it passes through the amount of money obtained by institutions which may allow them to offer higher wages. Therefore, removing endogeneity of the revenue should be sufficient to avoid any other endogeneity bias. This is why we propose to check whether our estimations are biased by endogeneity by instrumenting the revenue of institutions. Nevertheless, in order to confirm this economic intuition concerning the variables that are potentially endogenous, we have also tested for the endogeneity of the share of income devoted to research activities, the number of full time professors, their average salaries and the share of students in "hard" sciences; we found no clue in favor of the presence of endogeneity for these variables.

The instruments we use for the total revenue measured in 2005 are: the number of students enrolled in the institution and the share of undergraduates in 1990 and a dummy equal to one if the institution has a medical degree. From an economic perspective, we believe that there must be no endogeneity issue between these instruments and the score of Shanghai since the instruments are largely predetermined with respect to the ranking (remember that it was published for the first time in 2003) and are good predictors for the revenue of the institution in 2005. Furthermore, tested wether the student population in 2005 and the presence of a medical degree was a good predictor for the production of research. It appears that they are only good proxies for the number of professors, but are not significant to explain the production of research. This reinforce our intuition about the quality of these instruments. At the bottom of columns 3 and 4 of Table 3, we present several tests related to these instruments. All the tests confirm our economic intuition: first, the Sargan statistics suggest that our instruments are valid (i.e. uncorrelated with the error term, and that the excluded instruments are correctly excluded from the estimated equation). Second, the weak endogeneity tests seems to confirm the quality of the instruments.[5] Third and finally, the Hausman test for the presence of endogeneity suggests that the endogeneity issue is negligible when we do not control for the localization of the institutions (column 3), but is more important in the regressions with a fixed effect for the State where the institutions are located. Keeping in mind the organization of higher education, this is not surprising. States are responsible for the allocation of an important share of public funding. The allocation of these funds is partially determined by the performances of institutions. Therefore, it is normal to face more difficulties concerning the endogeneity at the State level rather than at the country level.

4.2 Further analysis

4.2.1 Robust estimations

Figure 1 presents the shape of the relationship between the score and the rank of the US institutions present in the Shanghai ranking. It suggests that the top institutions seem to perform significantly better than the others. Furthermore, looking at the descriptive statistics, it is clear that among the US institutions present in the Shanghai ranking, there are huge differences concerning their characteristics. A final clue in favor of the presence of outliers: the constant presented in estimation 3 of Table 3 is significantly different from zero. For this reason,

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[5] The null hypothesis of the Weak Intruments tests whose critical values are provided by Stoke and Yogo (2005) is that the instruments are weak. We focus on the relative bias of 2-SLS with respect to OLS regression. The critical values for weak instrument test based on 2-SLS bias for 3 instruments and one endogenous regressor are, respectively, for the 5 and 10% of maximal relative bias: 13.91 and 9.08 (see Stoke and Yogo (2005))

we have decided to check the validity of the results presented in the previous section through the use of robust estimators.

We run two robust estimations to identify the possible presence of outliers and their consequences. We use an S and an MS-estimator.[6] The results are presented in columns 1 and 2 of Table 4. From that, we use the identification procedure for "bad leverage points" developed by Rousseeuw et al. (1990). Based on graphical tools, the idea is to identify and exclude the observations that are both outliers in the X and in the Y-dimensions. The outliers in Y are the observations whose standardized robust residuals are outside the bounds [-2.25,2.25]. The leverage points (outliers in X) are the observations whose associated robust distance is higher than a particular threshold.

The leverage points are supposed to change the estimated coefficients and to increase the significativity of the results. Theoretically, if the residuals are normally distributed, the robust distance is distributed according to a $\chi^2_{p,}$ where p is the number of variables on which this distance is calculated. In the present case, nothing ensures that these assumptions are respected. Furthermore, introducing dummies into the analysis (with MS estimations), the assumptions which guarantee that the residuals are distributed according to a $\chi^2_{p,}$ are not respected anymore. For these reasons, we have tried several identification strategies for the leverage points (outliers in X). First, we identified them in the narrower way, every observation whose robust distance was higher than $\chi^2_{p,.90}$ was assumed to be a leverage point. Second, to test the robustness of the results we used the $\chi^2_{p,.95}$ and then the $\chi^2_{p,.80}$ thresholds. Qualitatively, these different thresholds do not modify the results. Figure 2 presents the standardized robust residuals obtained in by the S-estimation and the $\chi^2_{6,.90}$ thresholds and a zoom on the outliers identifies as "bad" while Figure 2bis present the residuals obtained from the MS-estimation.

When the bad outliers have been identified, we run weighted OLS and weighted 2-SLS regressions (respectively columns 3 to 8 of Table 4) where we assign a weight of 0 to the observations identified as "bad outliers" in the robust estimations and a weight of 1 to the others. The aim of this last step is to improve the efficiency of our estimations while getting rid of the biases due to the presence of outliers.

For every strategy discussed above, the results are very close, both with respect to the value

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[6] The S-estimator which is used in our estimations uses the Tukey Biweight function with a "tuning parameter" fixed at 1.547, Therefore, it resists to up to 50% of outliers within the observations. The MS-estimator is a robust estimator which allows to use dummies. This estimator iterates alternatively an S and an M estimation.

of the estimated coefficients and for their significativity.

The Hausman-type test proposed by Dehon et al. (2005)[7] confirms the validity of the estimation strategy proposed here, as it indicates that the bias due to the presence of outliers in the "normal" OLS regression dominates the efficiency loss due to the use of a robust estimator, but the efficiency gain of the weighted OLS regression dominates the bias due to the presence of not excluded outliers.

Finally, it is interesting to note that if we exclude the "bad leverage points", we exclude 6 or 7 of the 10 best ranked universities[8]. This implies that the results obtained are not driven by the top ranked universities even if (comparing the OLS regressions with the weighted OLS) the main results remain valid if we include these universities.

remembering that some of the observations should be seen as outliers, we also decided to apply the same identification procedure of outliers and test for a possible endogeneity issue by running weighted 2-SLS estimations on a subsample of universities. The results are very similar to the results presented in the previous section and the tests (discussed above) tend to indicate that the instruments which have been used are good. It is interesting to note that endogeneity does not appear to be an issue anymore. This result of the tests tends to indicate that endogeneity is driven by the (excluded) top ranked institutions that are able to attract more money because they are better ranked. For the other institutions, the effect of the production of research on their revenue would be less important and this latter variable can be treated as exogenous.

Finally, in order to ensure that we get rid of the outliers, we run two final weighted 2-SLS regressions were we give a weight of zero to the observations that are identified as outliers in the first or in the second step of the 2-SLS estimation. Results remain very similar, though the significativity is lower.

4.2.2 Quantile estimations

Since most of the institutions that are identified as outliers in the previous section are found among the top ones, it is interesting to investigate whether the best ranked institutions are

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[7] The idea of the test is to compare the coefficients of an efficient and consistent estimator under the null hypothesis of no contamination with the coefficients of an estimator that is quasi-consistent under the hypothesis that contamination is present. If the coefficient are similar, the efficiency gain justifies the use of the efficient estimation. If they are too different, the robust estimation will be preferred.

[8] With the other strategies discussed in the text, we could exclude up to 9 of the 15 first universities of the ranking.

not outliers, but instead behave differently with respect to their capacity to produce research. This idea is reinforced by the fact that the consequence of the presence of outliers appears in the constant rather than in the values of the betas which remain relatively stable through the different estimations presented.

In order to test this idea, we run quantile regressions on the institutions present in the Shanghai ranking. Figure 3 and 4 present a summary of quantile regressions by "icosile" (centile regressions by step of five units, blue lines) with the standard OLS results (red lines). As can be seen, there is no obvious indication of a differentiated behavior of the institutions depending on their rank. We also run inter quantile regressions, even at very polarized levels (5% to 95%), but did not find any insight in favor of a significant differentiated behavior of universities belonging to different part of the distribution.

4.3 Main results

Before turning to the discussion of the results presented in Table 3 and 4, it is important to remember how our results should be interpreted. The presented results are obtained in a cross-section of universities, in a static perspective. As no dynamic analysis has been run, a positive coefficient implies that it is possible to improve research production measured by the Shanghai ranking, but it does not imply that it would improve the rank of the university nor its score. According to the discussion presented above, results are not driven by the top, biggest and richest universities, but rather by the mass of U.S. universities present in the Shanghai ranking.

First, total revenue: As expected, the most powerful explanatory factor for the production of research is the total revenue of the institution. The variable used is the logarithm of the total revenue expressed in million $. This variable captures both the effect of being richer and bigger. Therefore, the positive coefficient implies a positive but strongly marginally decreasing effect of the total revenue on research production. Instead of using the logarithm of the revenue and therefore imposing the shape, we would have preferred to let the data decide of the shape. But even if a quadratic formulation yields the same kind of results (increasing and concave), the quality of the fit is lower. As shown in Table 3 and 4, even controlling for the quality and the size of the staff, the specialization of the institution and the share of revenue devoted to research, the significant impact of revenue remains valid.

Second, size: As discussed earlier, we can expect that a bigger institution produces more research than a smaller one. The size of an institution can be measured by the number of students, of staff, of a particular category within the staff, etc. We have tried many variables to capture this size effect. According to the different specifications we tested, the best measures are the number of full time professors, associate and assistant professors. We have summarized these two last categories of staff in one variable ("non professor") and obtain the following results: the total number of both faculty members and professors significantly increases the production of research measured by the Shanghai ranking. But, it appears that controlling for the number of professors, the number of "non professor" affects the production of research negatively. We believe that this result is related to the nature of the measure used for the Shanghai ranking. Obviously, we should not expect an assistant or associate professor to be among the Highly Cited researchers, nor to be awarded a Nobel prize, etc. Therefore, the cost of associate and assistant professors may be too high with respect to their production of research measured by the Shanghai criteria. From a static perspective, this staff would probably be more productive, according to the criteria, if additional professors that could appear in the Highly Cited researchers were enrolled. We should add that, as we do not have any dynamics in the model, we are not able to capture the fact that hiring young researchers could be a way to attract promising researchers and keep them with a slightly lower wage than what they could get in another institution. Finally, we do not find any complementarity effect between various staff categories. We have also tried several interactions, i.e. the number of members of the administrative staff per professor, of associate and assistant professors per professor, etc. but none of them yield significant results.

Third, revenues allocation: the share of the budget that is devoted to research expenses has a positive and significative impact on the production of research. Furthermore, we find important to control for the specialization of the institution. Using the share of students in hard sciences as a proxy for the specialization of the institution in these fields, we find that specialization significantly increases the production of research measured by the Shanghai criteria. In the next section, we will present a "sure" model were we disaggregate the criteria. We will show that the relative importance of hard sciences for an institution is not significant for the Sciences Citation Index, but it is significant for the three other criteria.

Fourth, staff quality: We measure the average quality of the professors by their average salary. Using this variable and its square together, we find a significant and very robust (both across models and specifications) U-shaped relationship between the quality and the production of research. Furthermore, there are institutions both in the decreasing and in the increasing part of the distribution of average salaries. This result suggests that, for a given level of revenue and number of professors, it is preferable to hire "the best or the worst" professors, otherwise, the performances of the institution would decrease. How can this be explained? Our intuition relates to the trade off between the different productive inputs. To produce research, workers (professors) are necessary, but so are infrastructure, tools, machines, etc. There might be an arbitrage between the amounts spent on professors and these other productivity factors. Therefore, hiring (on average) the cheapest professors might release means for the other factors. Increasing the proposed wages marginally seems to be too expensive with respect to the outside option for this money. In other words, increasing the proposed salary marginally is not sufficient to attract professors able to compensate the loss for the other productive aspects. But after a threshold (located around 80.000 US$, depending on the estimation), increasing the proposed wages allows to attract professors who are sufficiently productive to compensate the loss for the other factors. Paying sufficiently high wages may allow to attract "superstars", thus compensating the decrease of means for the other productive factors.

Fifth, we found important to discuss several aspects that were expected to affect the production of research, but for which we did not find any convincing evidence. Some of these "tests" are presented in Table 6. First of all, we expected the second mission of universities (to provide education) to affect the production of research significantly. We tried many variables and combinations of variables: the number of students per professor, the revenue per student, the structure of the student population to control for disadvantaged publics (including a variable with a relative share of Blacks, Hispanics and Blacks and Hispanics), the allocation of students among the different degrees (BA, MA and Ph.D.), the expenditures devoted to education, etc. But none of these remain significant when controlling for the revenue and the number of full-time professors. We have to conclude that there is no evidence that the mission of education affects - nor positively, nor negatively - the research measured by the Shanghai criteria of an institution. Another quite surprising result concerns the autonomy of institutions. Remember that among the top 10, nine institutions are private. Using the distinction "public" vs. "private"[9] institutions, we find no significant results while controlling for the total revenue. In other words,

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[9] To be more precise, all the "private" institutions present in the ranking are "private-non-for-profit".

it seems that a private institution is not more able to produce research, but might be better endowed (richer, able to hire more professors, etc.). We also tried to disentangle the origin of the revenue (public vs. private) to account for the fact that private sources might allow more autonomy to institutions, but this was not convincing either. Finally, we tried to build proxies for the autonomy of institutions using several indicators. We notably tried to replicate the measure proposed by Aghion et al. (2009) building a state autonomy index based on the share of private institutions in the States, but again, no convincing evidence was found. Other indexes were tested, such as the percentage of public versus private founds at the state level, but none appear significant.

Finally, we also tested the interactions between the different categories of staff. It appears that the inclusion of both the number of full time professors and the assistant and associate professors yield the best estimations. Nevertheless, aggregating them in one category leads to a positive and significant coefficient. But, the inclusion of other categories of staff as well as different interaction variables between these categories are never significant.

4.4 Additional issues and robustness check

In this section, we will discuss some issues that could have had an impact in our analysis.

A first issue concerns the possible selection bias that may affect our results. The Shanghai ranking provides the score for the 510 best ranked institutions in the world. As we do not have any information about the score of the other institutions, we are dealing with a truncated distribution for the institutions. We take this into consideration by applying the Heckman (1976) procedure using a first step estimation: a selection equation with variables that are not used in the second step: we use the Carnegie classification of universities and the total number of faculty staff (both part and full-time) as selection variables that are not present in the outcome equation. The idea of the Heckman estimation is to estimate:

$$E\left(shang\_prod2007_i | shang_i = 1\right) = \beta_1 + \sum_{j=1}^{p} \beta_j X_{ji} + \frac{\sigma_{\varepsilon u}}{\sigma_{\varepsilon}} \lambda_i \tag{4}$$

where λ_i is obtained by a probit estimation for the selection procedure.

As discussed before, we restrain our sample to the institutions that spend at least 2% of their revenue on research activities and that deliver Ph.Ds. In this case, if we control for the State of the institution, the selection bias is not an issue, the Mills coefficient (λ_i) is not significant.[10]

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[10] Note that if we do not control for the localization of the institution, the Mills coefficient is significant at 10%,

A second issue relates to the construction of the dependent variable. We could have doubts about the effect of the arbitrary weights given to the four criteria of Shanghai. We therefore estimate the same regressions with the two other dependent variables proposed. We used, in turn, the score of Shanghai and the "shang_pca", the score obtained through a principal components analysis on the four criteria retained for the core of the analysis. As expected with respect to the correlation coefficients presented in Table 2, the results are very similar to the ones presented and discussed in the paper. Therefore, we will not present the corresponding tables.[11]

A third issue, also related to the aggregation of the criteria, concerns the differentiated effects of each of the explanatory variable on every aspect of the explained variables. To get a more precise analysis of the differentiated effect of each variable, we ran a Seemingly Unrelated Estimation (SURE model) on the four main Shanghai criteria (*Award*, *HiCi*, *N&S* et *SCI*). Table 5 presents the results. The main results are not affected, notably the U-shaped relationship between the average quality of professors and the production of research remain valid. Two major exceptions appear. First, the relative importance of "hard" sciences specialization of an institution has no effect for the criterion *SCI*. This confirms the intuition that the ranking is biased in favor of a specialization in "hard" sciences, except for the last criterion. Second, the revenue has no significant effect on the criterion "*award*". It appears that the actual level of revenue does not affect this criterion. We believe that this test yields important results: many economists are concerned by the arbitrary weight given to each criterion. The fact that, estimated independently (but related through the error term) the effects remain very similar suggests that the arbitrary aggregation of criteria has a very limited impact on the quality of the results presented in this paper.

A last robustness check was performed with another dependent variable: on the basis of the information available in the Times Higher Education Ranking. Unfortunately, this ranking is only available for 50 U.S. universities and there are important significativity issues. Nevertheless, the results are not contradictory if we use the score obtained by the universities classified in the THES.

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but we found more important to control for both the endogeneity issue and the presence of outliers than for the selection bias that disappears when we control for the localization of universities.

[11] These tables are available on request.

5 Conclusions and policy implications

The aim of this paper is to analyze the determinants of the production of research by U.S. universities. Even if the use of the information contained in the Shanghai ranking restrains the scope of the study to a particular kind of research (the top level academic research), the Shanghai criteria constitute interesting measures of research production. We must bear in mind that our dependent variable is a composite index aggregating different criteria, all assessing different aspects of the production of research. This variable lies between 0 and 100, but this does not our results as long as 1) we do not have selectivity bias[12] and 2) we work in a static framework.[13]

From an econometric perspective, we consider that the endogeneity issue might be important, but show that it is negligible when we take the presence of outliers into consideration. Indeed, endogeneity seems to be driven by the top level universities able to attract more money because they appear in hhigh position in the ranking. Higher education in the U.S. is not homogenous at all and the estimations are affected by the presence of outliers, notably so-called "bad" outliers. This is why we use robust estimators to identify the different kinds of outliers and then use weighted OLS estimations to exclude the bad leverage points. We also run different weighted 2-SLS estimations to control for the presence of endogeneity. Finally, we investigate the possibility for the institutions being present in different parts of the distribution to behave differently by running some quantile and inter-quantile regressions. We did not find major differences. Last but not least, we estimate a model of seemingly unrelated regressions (SURE). The aim is to check whether the effects obtained in previous sections are driven by the aggregation rule applied to the Shangai criteria or not. It appeared that our control variables seem to have a relatively stable effect on the different criteria used for the Shanghai ranking.

Among the results, some were expected: controlling for the size of the academic staff, the production of research increases with revenue, but this relationship is characterized by decreasing returns. The quality of the professors (measured by their average salary) appears to have a

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[12] We have shown that if we focus on intitutions spending more than 2% of their income for research activities and if we control for the State of the institution, selection bias is not an issue.

[13] It should be noted that in a static framework, a university improving its production of research should expect an increase in the score of Shanghai. But in a dynamic setting where the score is computed every year according to the best institution, this would not necessarily be the case. Suppose that a university X increases its production of research, but at the same time, the best university (let's say Harvard), improves its research proportionally more, this would lead to a fall in the score of Shanghai for university X even if it has improved its research.

convex effect on the production of research, with a significant share of the institutions (more than 30%) on the decreasing part of the curve. This result is very robust between specifications. We believe that this is due to the trade-off between the quality of the hired professors (and their costs) and the other expenses needed to produce research. By contrast, hiring assistant or associate professors seems to be associated with a lower research level as measured by the Shanghai ranking. This is probably linked to the Shanghai criteria, all focussing on different aspects of top level academic research, often not yet accessible to young researchers. One may expect that hiring a young researcher constitutes an investment for the future, but unfortunately, we cannot evaluate the relevance of this assumption with our database. Finally, we show how the ranking privileges institutions that are specialized in hard sciences and that devoting a higher share of the revenue for research increases its production.

Several preconceived ideas are not supported by our estimations. First of all, we could not find evidence in favor of a significant effect of the teaching mission of institutions on the production of research: the estimated coefficients of the number of students, the student per teacher and the professor ratio are never significant. Another common belief relates to the control of the institution. Even if there are nine private institutions among the top 10 in the US, controlling for their revenue, the nature of their control has no significant effect on their production of research. In the same vein, we have tried several specifications to isolate a measure of the autonomy, building several State autonomy indexes, for example, but we never found any concluding insight.

Finally, it is important to come back to one of the underlying questions: what is the social value of the Shanghai Ranking? What does it mean to increase one's score by two points? What are the implications for universities, on public and private funding and for society?

Much work still to be done to answer these questions and to evaluate the effects of academic research on growth, welfare, etc. In the meantime, our analysis has given us the opportunity to identify several leverages that are potentially able to improve to production of research by U.S. universities. Given the increasing attention paid by everyone, in particular universities and their Boards to international rankings, improving the produced research and ensuring a high rank in these rankings have become important targets. Furthermore, in the near future, this will probably become a key factor in attracting more funding from both the private and the public sectors.

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Appendix

A Figures

Figure 1: The Shanghai Score by rank of US universities

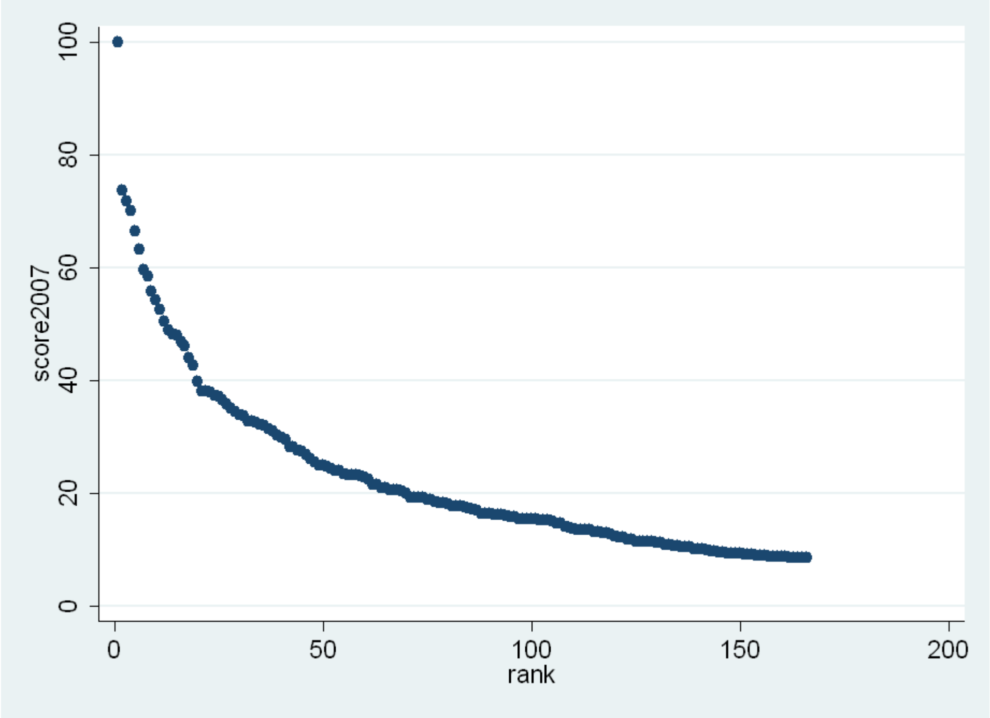


Figure 2: Graphical tool used to identify the bad leverage points, S-estimations

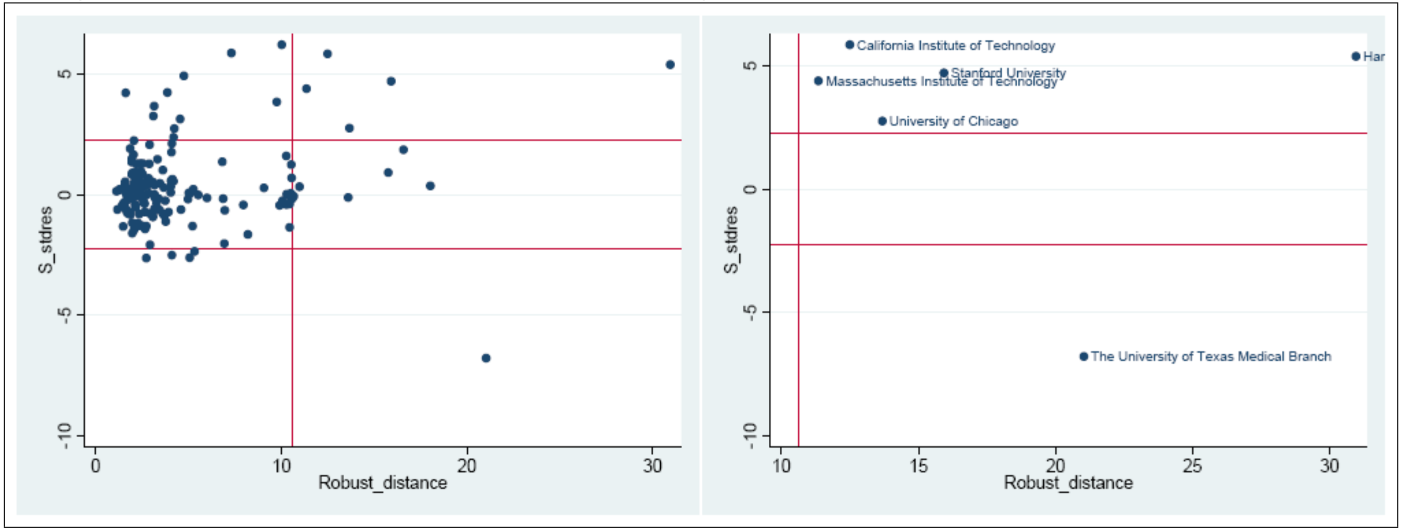


Figure 2bis: Graphical tool used to identify the bad leverage points, MS-estimations

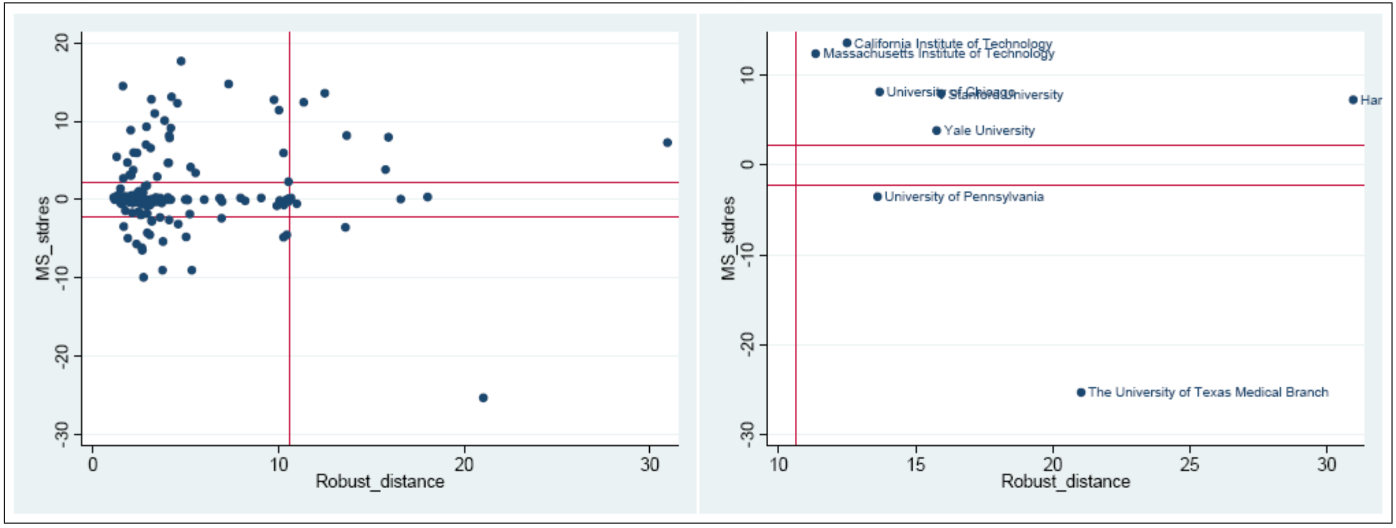
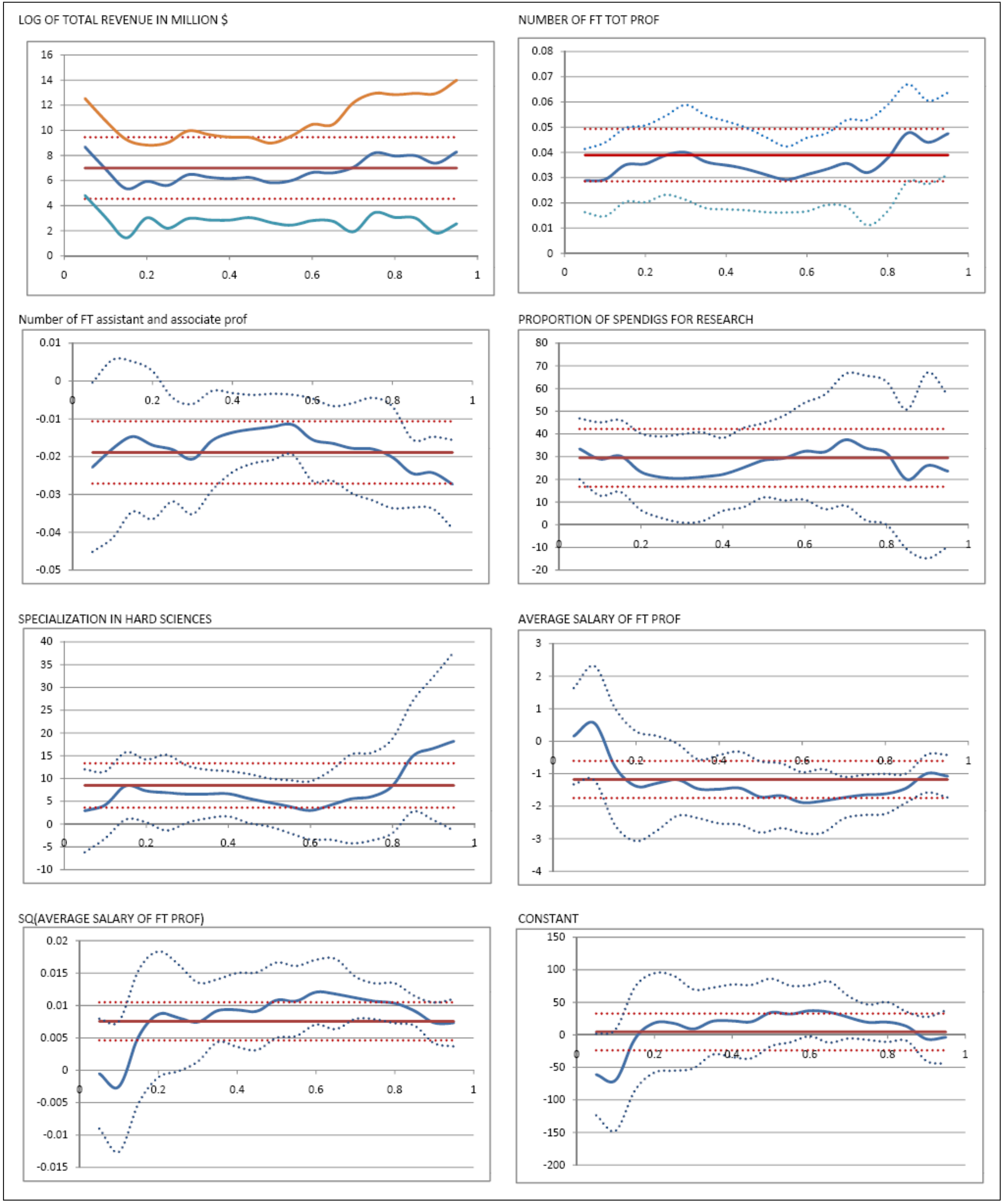
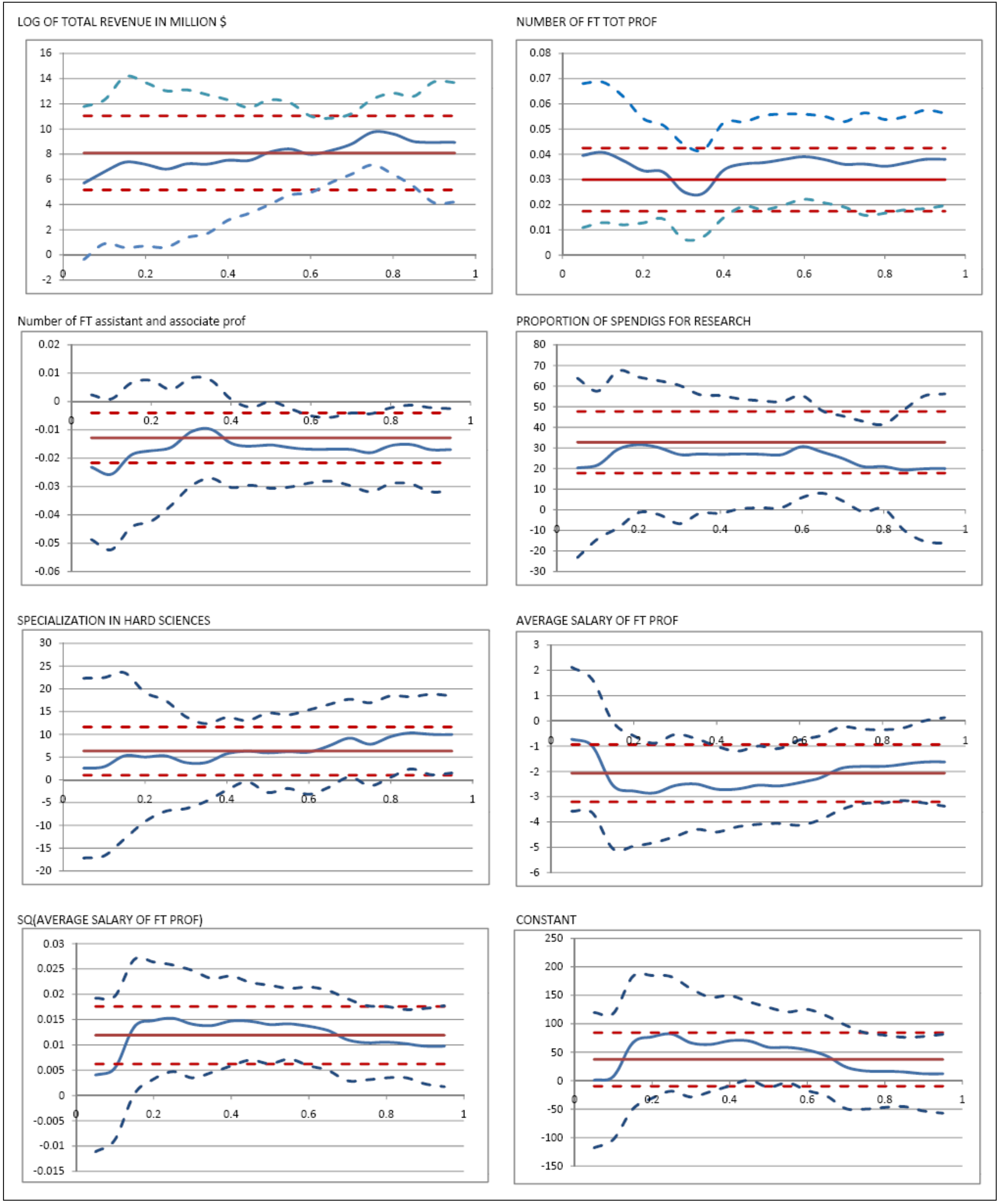


Figure 3: Summary of quantile and WOLS regressions (for the 5th, the 10, the 15th etc. centiles) without state dummies



Solid red line: standard WOLS estimation
Solid blue line: quantile regression
Dashed lines: 95% confidence interval

Figure 4: Summary of quantile and WOLS regressions (for the 5th, the 10, the 15th etc. centiles) with state dummies



LOG OF TOTAL REVENUE IN MILLION $

NUMBER OF FT TOT PROF

Number of FT assistant and associate prof

PROPORTION OF SPENDIGS FOR RESEARCH

SPECIALIZATION IN HARD SCIENCES

AVERAGE SALARY OF FT PROF

SQ(AVERAGE SALARY OF FT PROF)

CONSTANT

Solid red line: standard WOLS estimation
Solid blue line: quantile regression
Dashed lines: 95% confidence interval

B Tables

Table 1: Summary statistics for US universities "doing research"

	Institutions present in the Shanghai Ranking	Not in the Ranking, but spending more than 2% in research and offering doctorate
Number of institutions	164	214
controlD1	70%	62%
medical	62%	20%
proportion of students is "hard" sciences	39% (0.25)	35% (0.30)
Total revenue in $1.000.000	1231.061 (1058.23)	235.27 (401.05)
Number of full time professors	359.72 (225.13)	104.31 (83.67)
Number of assistant and assiciate professors	445.17 (236.25)	199.11 (141.36)
Part and full time faculty staff	2122.56 (1238.89)	602.66 (513.09)
Number of students	20391.09 (12875.89)	8985.89 (7667.99)
Proportion of undergrad students	0.56 (0.21)	0.58 (0.208)
Average salary of full time professors	93.05 (16.05)	70.23 (20.8)

Sources: IPEDS
Standard deviations in parenthesis

Table 2: Correlation between the differents criteria of the Shanghai Ranking

	Score of Shanghai	Shangperf	Shangpca	Alumni	Award	HiCI	NS	SCI	Size
score of Shanghai	1								
Shangprod	0.996	1							
Shangpca	0.994	0.999	1						
Alumni	0.845	0.802	0.792	1					
Award	0.879	0.865	0.842	0.795	1				
HiCi	0.954	0.964	0.970	0.729	0.751	1			
NS	0.957	0.959	0.961	0.762	0.799	0.909	1		
SCI	0.852	0.872	0.889	0.626	0.555	0.885	0.809	1	
Size	0.893	0.872	0.866	0.741	0.818	0.823	0.871	0.662	1

Ranking of 2007, data available at www.arwu.org

Table 3: OLS and 2 SLS estimations

	OLS		2-SLS	
	(1)	(2)	(3)	(4)
COEFFICIENT			shangperf2007	
log of total revenue in million $	7.926***	9.224***	5.009**	5.806***
	(1.37)	(1.57)	(1.96)	(1.81)
number of full time professors	0.0425***	0.0322***	0.0474***	0.0376***
	(0.0055)	(0.0068)	(0.0053)	(0.0050)
number of full timme assistant and associate prof	-0.0241***	-0.0178***	-0.0229***	-0.0162***
	(0.0055)	(0.0063)	(0.0037)	(0.0037)
proportion of spendings for research	30.65***	36.73***	29.40***	35.18***
	(7.78)	(9.20)	(6.94)	(6.51)
proportion of students in "hard" sciences	7.364**	4.670	9.054***	7.215***
	(3.62)	(3.97)	(2.74)	(2.72)
average salary of professors	-1.490***	-2.154***	-1.522***	-2.076***
	(0.42)	(0.48)	(0.30)	(0.34)
sq(average salary of professors)	0.00914***	0.0120***	0.00963***	0.0121***
	(0.0023)	(0.0026)	(0.0015)	(0.0016)
Constant	14.69	44.91*	30.40*	49.49***
	(20.9)	(25.0)	(17.9)	(17.3)
geographical dummy for States	no	yes	no	yes
Observations	159	159	159	159
R-squared	0.85	0.90	0.84	0.89
centered			0.842	0.894
sargan statistic			4.490	3.243
p-value of Sargan stat			0.106	0.198
Cragg-Donald F statistic - weak identification test			24.60	18.90
Hausman test statistic - endogeneity test			3.453	5.958
p-value of Hausman stat			0.063	0.0146
Instrumented variables			log of total revenue in million $	
excluded instruments			number of students in 1990 proportion undergrad in 1990 presence of medical degree	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Robust, weighted OLS and weighted 2 SLS estimations

	M-estimation	MS-estimation	Weighted OLS(*)		Weighted 2-SLS(**)		Weighted 2-SLS(***)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
COEFFICIENT				shangperf2007				
log of total revenue in million $	5.037***	7.024***	7.000***	8.096***	5.180***	6.137***	3.821	4.731**
	(0.82)	(0.25)	(1.25)	(1.50)	(1.63)	(1.54)	(2.46)	(1.93)
number of full time professors	0.0243***	0.0206***	0.0389***	0.0299***	0.0418***	0.0325***	0.0418***	0.0296***
	(0.0052)	(0.00061)	(0.0053)	(0.0064)	(0.0045)	(0.0043)	(0.0048)	(0.0050)
number of full timme assistant and associate prof	-0.00502	-0.00500***	-0.0189***	-0.0128***	-0.0179***	-0.0116***	-0.0164***	-0.00426
	(0.0034)	(0.00040)	(0.0042)	(0.0045)	(0.0034)	(0.0033)	(0.0047)	(0.0051)
proportion of spendings for research	18.75***	25.53***	29.48***	32.78***	28.58***	31.89***	28.49***	54.68***
	(5.90)	(1.77)	(6.50)	(7.63)	(6.27)	(5.80)	(6.17)	(10.4)
proportion of students in "hard" sciences	4.722**	2.960***	8.494***	6.326**	9.578***	7.797***	8.493***	2.808
	(2.05)	(0.38)	(2.48)	(2.70)	(2.49)	(2.40)	(2.75)	(2.95)
average salary of professors	-1.266***	-2.933***	-1.177***	-2.067***	-1.221***	-1.937***	-1.349***	-1.952***
	(0.31)	(0.20)	(0.29)	(0.58)	(0.34)	(0.43)	(0.37)	(0.57)
sq(average salary of professors)	0.00827***	0.0159***	0.00755***	0.0119***	0.00798***	0.0115***	0.00894***	0.0123***
	(0.0016)	(0.00092)	(0.0015)	(0.0029)	(0.0018)	(0.0022)	(0.0021)	(0.0028)
Constant	20.64	96.04***	4.505	37.34	15.33	41.13**	27.38	44.85*
	(15.2)	(11.1)	(14.4)	(24.0)	(18.4)	(19.0)	(23.3)	(26.1)
geographical dummy for States	no	yes	no	yes	no	yes	no	yes
Observations	159	159	153	151	153	151	137	98
R-squared	.	.	0.83	0.89	0.83	0.88	0.84	0.92
centered					0.827	0.883	0.836	0.917
sargan statistic					2.551	0.914	0.528	2.372
p-value of Sargan stat					0.279	0.633	0.768	0.305
Cragg-Donald F statistic - weak identification test					28.68	19.35	22.91	161.5
Hausman test statistic - endogeneity test					2.043	2.709	1.580	0.965
p-value of Hausman stat					0.1529	0.1	0.2088	0.3259
Instrumented variables					log of total revenue in million $			
excluded instruments					number of students in 1990 proportion undergrad in 1990 presence of medical degree			

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

(*) Weight of zero for the "bad" outliers identified in the S or MS-estimation

(**) Weight of zero for outliers at the seconp step of the 2-SLS estimation (same as for the W-OLS of table 3)

(***) Weight of zero for outliers at any of the two steps of the 2-SLS estimation

Table 5: Seemingly unrelated estimations (SURE) and weighted SURE

	SURE estimation for all institutions present in the Shanghai ranking							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
COEFFICIENT	award2007	hici2007	ns2007	sci2007	award2007	hici2007	ns2007	sci2007
log of total revenue in million $	0.897	8.295***	8.192***	14.32***	1.466	10.28***	9.769***	15.39***
	(2.15)	(1.24)	(1.42)	(0.88)	(2.15)	(1.10)	(1.32)	(0.86)
number of full time professors	0.0450***	0.0549***	0.0412***	0.0288***	0.0346***	0.0432***	0.0281***	0.0230***
	(0.0086)	(0.0050)	(0.0057)	(0.0035)	(0.0090)	(0.0046)	(0.0055)	(0.0036)
number of full timme assistant and associate prof	-0.0295***	-0.0277***	-0.0285***	-0.0105***	-0.0217***	-0.0212***	-0.0189***	-0.00936***
	(0.0070)	(0.0040)	(0.0046)	(0.0029)	(0.0072)	(0.0037)	(0.0044)	(0.0029)
proportion of spendings for research	16.48	27.93***	38.50***	39.68***	27.86**	30.32***	44.12***	44.62***
	(13.1)	(7.56)	(8.69)	(5.38)	(12.9)	(6.57)	(7.90)	(5.12)
proportion of students in "hard" sciences	13.04***	10.42***	7.272**	-1.276	13.00***	5.883**	4.422	-4.618**
	(4.91)	(2.83)	(3.25)	(2.01)	(4.96)	(2.53)	(3.05)	(1.97)
average salary of professors	-3.065***	-1.165***	-1.583***	-0.147	-3.548***	-2.049***	-2.207***	-0.809***
	(0.57)	(0.33)	(0.37)	(0.23)	(0.67)	(0.34)	(0.41)	(0.27)
sq(average salary of professors)	0.0188***	0.00735***	0.00943***	0.000981	0.0209***	0.0111***	0.0121***	0.00393***
	(0.0029)	(0.0017)	(0.0019)	(0.0012)	(0.0032)	(0.0016)	(0.0020)	(0.0013)
Constant	111.5***	-4.957	17.52	-65.28***	117.2***	0	0	0
	(29.7)	(17.1)	(19.7)	(12.2)	(37.0)	(0)	(0)	(0)
geographical dummy for States	no	no	no	no	yes	yes	yes	yes
Observations	159	159	159	159	159	159	159	159
R-squared	0.64	0.84	0.76	0.90	0.74	0.91	0.85	0.93

	SURE estimation for institutions present in the Shanghai ranking excluding "bad outliers"							
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	award2007	hici2007	ns2007	sci2007	award2007	hici2007	ns2007	sci2007
log of total revenue in million $	-0.985	7.468***	7.210***	14.31***	-0.350	9.110***	8.599***	15.02***
	(1.92)	(1.18)	(1.32)	(0.83)	(1.91)	(1.05)	(1.23)	(0.81)
number of full time professors	0.0397***	0.0518***	0.0369***	0.0270***	0.0309***	0.0418***	0.0257***	0.0210***
	(0.0077)	(0.0047)	(0.0053)	(0.0033)	(0.0079)	(0.0043)	(0.0051)	(0.0033)
number of full timme assistant and associate prof	-0.0195***	-0.0235***	-0.0227***	-0.00974***	-0.0117*	-0.0178***	-0.0138***	-0.00788***
	(0.0064)	(0.0039)	(0.0044)	(0.0028)	(0.0065)	(0.0036)	(0.0042)	(0.0027)
proportion of spendings for research	10.01	27.97***	38.19***	41.75***	15.59	28.01***	40.86***	46.66***
	(12.0)	(7.33)	(8.23)	(5.16)	(11.6)	(6.38)	(7.46)	(4.92)
proportion of students in "hard" sciences	15.70***	11.21***	7.500**	-0.441	15.85***	7.230***	5.452*	-3.230*
	(4.54)	(2.78)	(3.13)	(1.96)	(4.44)	(2.45)	(2.87)	(1.89)
average salary of professors	-3.076***	-0.797**	-1.253***	0.417	-4.417***	-1.621***	-2.202***	-0.0281
	(0.64)	(0.39)	(0.44)	(0.28)	(0.85)	(0.47)	(0.55)	(0.36)
sq(average salary of professors)	0.0189***	0.00547***	0.00779***	-0.00201	0.0259***	0.00913***	0.0124***	0.0000314
	(0.0034)	(0.0021)	(0.0023)	(0.0015)	(0.0043)	(0.0024)	(0.0028)	(0.0018)
Constant	120.9***	-18.07	6.758	-91.59***	165.5***	0	51.47*	-64.74***
	(32.0)	(19.6)	(22.0)	(13.8)	(42.4)	(0)	(27.3)	(18.0)
geographical dummy for States	no	no	no	no	yes	yes	yes	yes
Observations	153	153	153	153	151	151	151	151
R-squared	0.55	0.82	0.72	0.90	0.67	0.89	0.82	0.93

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Robustness chek for several variables of interest

				Weighted OLS(*)			
	(1)	(3)	(5)	(2)	(4)	(6)	(7)
COEFFICIENT				shangperf2007			
dummy if institution is private		0.864					
		(1.44)					
share of revenue from private sources			-2.380				
			(4.19)				
total number of students				0.0000469			
				(0.000089)			
total number of undergraduate students					-0.0000114		
					(0.00014)		
number of student par academic						0.0761	
						(0.068)	
revenue per student							-1.326
							(3.15)
log of total revenue in million $	8.096***	8.179***	8.297***	8.039***	8.087***	7.980***	8.126***
	(1.50)	(1.51)	(1.45)	(1.56)	(1.48)	(1.57)	(1.50)
number of full time professors	0.0299***	0.0293***	0.0293***	0.0285***	0.0302***	0.0302***	0.0295***
	(0.0064)	(0.0065)	(0.0064)	(0.0067)	(0.0075)	(0.0064)	(0.0062)
number of full timme assistant and associate prof	-0.0128***	-0.0129***	-0.0128***	-0.0132***	-0.0127***	-0.0122***	-0.0125***
	(0.0045)	(0.0044)	(0.0044)	(0.0045)	(0.0045)	(0.0044)	(0.0044)
proportion of spendings for research	32.78***	32.94***	30.59***	33.06***	32.74***	33.30***	33.19***
	(7.63)	(7.58)	(8.65)	(7.61)	(7.72)	(7.42)	(7.88)
proportion of students in "hard" sciences	6.326**	5.992**	6.141**	6.982**	6.236**	8.283**	7.045**
	(2.70)	(2.79)	(2.74)	(2.94)	(2.84)	(3.29)	(3.04)
average salary of professors	-2.067***	-2.096***	-2.075***	-2.075***	-2.063***	-2.102***	-2.160***
	(0.58)	(0.59)	(0.58)	(0.59)	(0.57)	(0.59)	(0.63)
sq(average salary of professors)	0.0119***	0.0121***	0.0120***	0.0120***	0.0118***	0.0122***	0.0124***
	(0.0029)	(0.0030)	(0.0030)	(0.0030)	(0.0029)	(0.0030)	(0.0033)
Constant	37.34	37.15	37.77	37.41	37.33	36.22	40.78
	(24.0)	(24.1)	(24.2)	(24.4)	(24.0)	(24.3)	(25.9)
geographical dummy for States	yes	yes	yes	yes	yes	yes	yes
Observations	151	151	151	151	151	151	151
R-squared	0.89	0.89	0.89	0.89	0.89	0.89	0.89

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

(*) Weight of zero for the "bad" outliers identified in the MS-estimation

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