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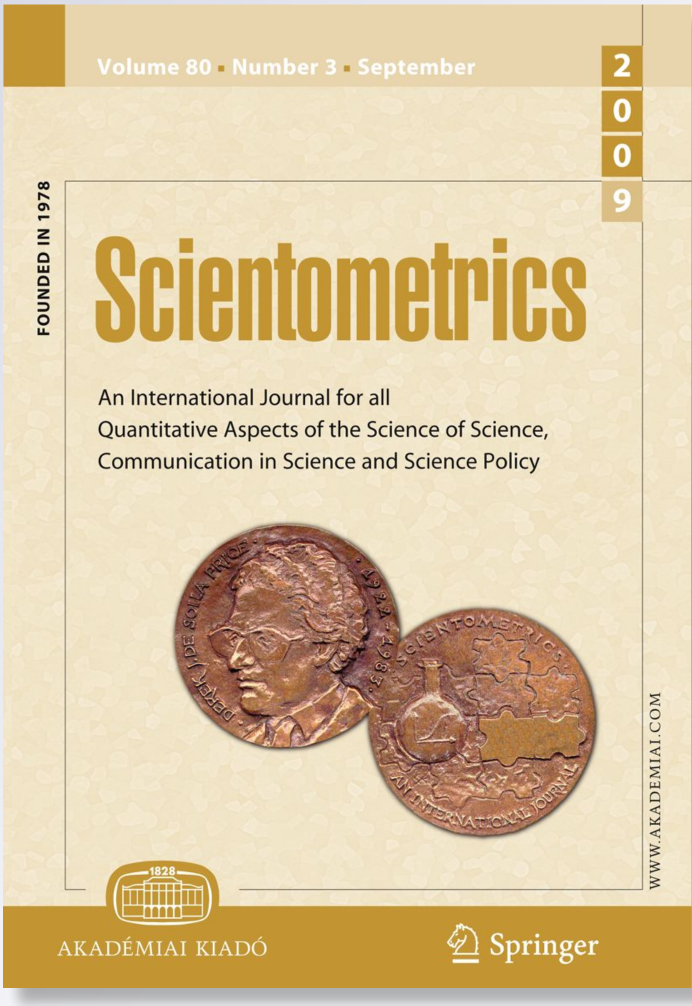

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Abstract In academia, the term "inbreeding" refers to a situation wherein PhDs are employed in the very same institution that trained them during their doctoral studies. Academic inbreeding has a negative perception on the account that it damages both scientific effectiveness and productivity. In this article, the effect of inbreeding on scientific effectiveness is investigated through a case study. This problem is addressed by utilizing Hirsch index as a reliable metric of an academic's scientific productivity. Utilizing the dataset, constructed with academic performance indicators of individuals from the Mechanical and Aeronautical Engineering Departments, of the Turkish Technical Universities, we demonstrate that academic inbreeding has a negative impact on apparent scientific effectiveness through a negative binomial model. This model appears to be the most suitable one for the dataset which is a type of count data. We report chi-square statistics and likelihood ratio test for the parameter alpha. According to the chi-square statistics the model is significant as a whole. The incidence rate ratio for the variable "inbreeding" is estimated to be 0.11 and this ratio tells that, holding all the other factors constant, for the inbred faculty, the *h*-index is about 89% lower when compared to the non-inbred faculty. Furthermore, there exists negative and statistically significant correlation with an individual's productivity and the percentage of inbred faculty members at the very same department. Excessive practice of inbreeding adversely affects the overall productivity. Decision makers are urged to limit this practice to a minimum in order to foster a vibrant research environment. Furthermore, it is also found that scientific productivity of an individual decreases towards the end of his scientific career.

Keywords Academic inbreeding · Scientific effectiveness · Turkish universities

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In academia, the term "inbreeding" refers to a situation wherein PhDs are employed in the very same institution that trained them during the course of their doctoral studies. Academic inbreeding is, perceived negatively amongst many colleagues, on the account that it damages the scientific productivity and effectiveness. Nonetheless, all that there exists is mere speculation without hard evidence. There were hardly enough serious and conclusive research on this subject until recently. However, new studies go one step further and report a number of conclusive findings with quantitative results. Horta et al. (2010) conclude that academically inbred faculty members are relatively more centered on their institutions and less open to the scientific community as a whole. Moreover, they also report that academic inbreeding is detrimental in terms of scientific output. This study primarily aims to look into this issue using other variables (such as *h*-index, project management data etc.) that are also indicative of scientific effectiveness.

At this point, it is also worth noting that, in certain research cultures, such one in the United States academic inbreeding is particularly frowned upon. Presently in the United States, levels of academic inbreeding in higher education institutions are typically less than 20% and often below 10% especially in the leading research institutions. On the other hand, in some other parts of the world such as China, India, Korea, Europe and Turkey academic inbreeding is a very common practice with inbreeding ratios in excess of 50%. This situation probably has some cultural or contingent factors to itself that need to be addressed from a sociological perspective. Yet such a treatment is beyond the scope of this study. Present work aims to understand the effects of university hiring practices on its scientific output.

Aside from its widespread practice in certain parts of the world, one needs to examine the arguments against academic inbreeding, in order to understand why it is perceived to be a damaging hiring policy. There are indeed a number of them. First and foremost, it limits the exchange of scientific knowledge and leads to academic fossilization. Secondly, it prevents faculty appointments being made on a merit basis and therefore limits the talent pool within which the selection is to be made.

Consequently, not only it is crucial to gain a proper understanding as to the effects of academic inbreeding from a perspective of either scientific or technological policy making, but also from a perspective of society that thrives on a knowledge based economy, since universities are indeed nothing but fundamental pillars of innovation as pointed out by Rosenberg and Nelson (1994). As a direct consequence university innovation is quite important for the local industry. Solid research findings prove this relationship. For example, Jaffe (1989) reports a significantly positive correlation between university research expenditures and local patenting rates. Additionally, Nelson (1993) demonstrates that countries with strongest firms in high-tech sectors also have equivalently strong university research in that field.

Dataset and methodology

In this paper a case study from Turkish Technical Universities is presented. As we are concerned about university research activity and industrial innovation within the context of a knowledge driven economy, the very choice of technological disciplines seems to be well justified. In Turkey there exist four technical universities in total, namely; Istanbul Technical University (ITU), Karadeniz Technical University (KTU), Middle East Technical University (METU) and Yıldız Technical University (YTU). All of these public schools are funded by the Turkish government. Moreover, all are PhD granting institutions.

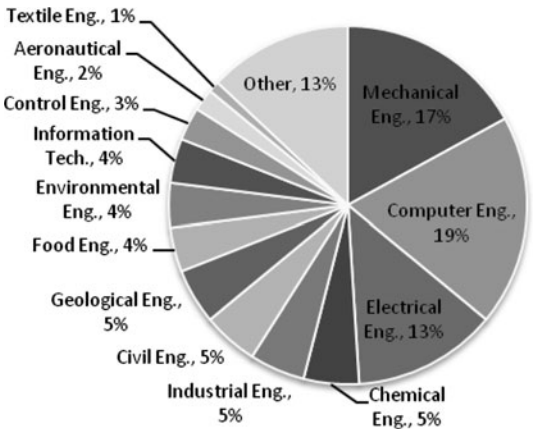


Fig. 1 Distribution of Turkish researchers with a doctoral degree across technological disciplines (*source*: Turkish Scientific and Technical Research Council)

Faculty salaries are essentially the same. They are all located in major cities, and are surrounded by vibrant economic and industrial activity. Research funding schemes (grants via Turkish Scientific and Technical Research Council or State Planning Organization) are also the same. All four institutions recruit young individuals as undergraduates through a countrywide annual university entrance examination. Their student bodies typically consist of the top 5% of the candidate pool. Therefore there is not much of a difference between student bodies on an intellectual level. This situation is noteworthy since it continues in the graduate level education as well. Consequently, the dataset is constructed from the faculty members of Mechanical and also Aeronautical/Aerospace Engineering Departments of Turkish Technical Universities. This choice is made so as to alleviate the heterogeneity effects across various technological disciplines.

Mechanical Engineering itself has a broad application spectrum and therefore is a key technological discipline. Aeronautical and Aerospace Engineering are very close fields to mechanical engineering research topics and citation conventions are similar as well. These two are also key disciplines that drive innovation. This statement is also underlined by Fig. 1, which graphically depicts the distribution of Turkish researchers holding a PhD across technological disciplines. Seventeen percent of all researchers in technological fields happen to be mechanical engineers. Two percent of them are aeronautical/aerospace engineers. Computer scientists and electrical engineers constitute to 19 and 13% share of the researcher body respectively. Distribution of individuals within our dataset across universities and academic ranks is tabulated in Table 1. Furthermore the distribution of faculty members across academic ranks is also graphically depicted in Fig. 2 for better visualization.

Majority of the data is obtained either through departmental websites or personal curriculum vitae. Publication data and bibliometric information are gathered from Web of Science (http://apps.isiknowledge.com). Only journal articles in the science citation index (SCI) are considered. Project management data is obtained by querying the TÜBİTAK-ARBİS database (https://arbis.tubitak.gov.tr). Data is collected as of December 2010. There are 236 individuals within the dataset in total. Only two universities in Turkey (ITU and METU) have Aeronautical and Aerospace Engineering Departments. In our analysis mechanical and aeronautical engineering departments are treated as a single department due to the aforementioned similarities between these two technological fields.[1] As

[1] Similar results are obtained when only mechanical engineering departments are considered.

Table 1 Distribution of scholars within the dataset across schools and academic ranks

	Professor	Associate Professor	Assistant Professor	Instructor	Total
ITU	45	18	26	7	96
KTU	13	4	9	1	27
METU	37	5	21	1	64
YTU	20	7	22	0	49
Overall	115	34	78	9	236

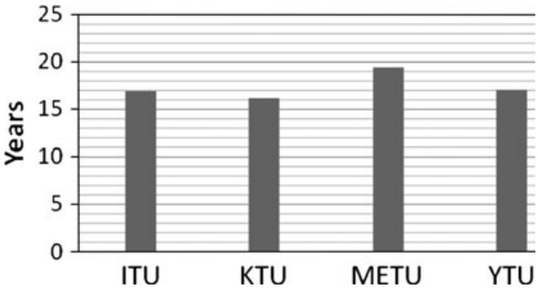


Fig. 2 Average professional age of faculty members across Turkish Technical Universities

demonstrated by Table 1, for all of these four schools, distributions across academic ranks are much similar to one another with almost half of the faculty being full professors and about one-third of them being assistant professors. Associate professors and especially instructors occupy a relatively low percentage. This rather unusual distribution is primarily due to the tenure system that is in effect in Turkey. An individual becomes tenured once appointed as an associate professor. Furthermore, in order to become an associate professor one has to pass a two tier centrally administered (by the Turkish Higher Education Council) jury exam. Therefore, for public universities tenure criteria do not vary one institution to the other. Furthermore, once an individual completes a 5 years term at the rank of associate professor he can apply for full professorship, then the university decides whether the individual is to be promoted or not. In addition, although tenure is gained at the associate professor level, in practice there is job security from the beginning. This whole promotion scheme effectively describes the situation seen in Table 1, and also explains the relatively low percentage of individuals at the associate professor rank. Nevertheless, it would be worth mentioning that obtaining tenure and subsequent promotion to professorship has been according to these criteria since the early 1990s. Before then obtaining tenure had relatively been easier and did not require much research activity (such as scientific publications or project management) at all.

Figure 2 shows the distribution of average professional age across Turkish technical universities (note that the data consists of only the departments of interest). The overall average is about 18 years. As shown in Fig. 2, the distribution is fairly uniform, therefore comparison of h-indices in the proceeding sections of the paper, would not be biased in that manner. It is well known that most bibliometric indicators favor individuals that have a longer career due to accumulation of citations and number of publications for that matter. In this regard only METU has a slight advantage over the others. ITU on the other hand has the youngest faculty members and therefore is at a slight disadvantage.

Moreover, the need for accountability in higher education has led research authorities and administrators to assess scientific performance using single indices that facilitate comparisons and rankings (Panaretos and Malesios 2009). In terms of methodology, in order to distinguish the performance of inbred individuals from their non-inbred colleagues there needs to be a figure of "academic merit" by which this distinction can be made inarguably. There are of course universally accepted measures of scientific output. Most of these are bibliometric indicators. Such measures are often used to rank institutions of higher education or individual departments. Recently Lazaridis (2009) utilized *h*-index in order to rank chemistry departments in Greece. Lazaridis (2009) concludes that rankings are valuable since they spur competition between departments and they provide a strong motive for meritocracy in faculty hiring. This is especially important for countries like Turkey where favoritism and political interference are still practiced. We will follow a similar approach and henceforth use the *h*-index an indicator of apparent scientific effectiveness in this study.

Hirsch (2005) in his much celebrated paper, points out that "a scientist has index h if h of his N_p papers have at least h citations each, and the other $(N_p - h)$ papers have at most h citations each". For example, a scientist with an index of ten has published ten papers with at least ten citations each. A zero *h*-index characterizes authors that have at best published papers that have had no visible impact at all.

Therefore by this definition the *h*-index reflects both the number of publications and the number of citations per publication (Glanzel 2006). This index works best only for comparing scientist working in the same field, since citation conventions might differ among different fields (Hirsch 2005). This also justifies our choice of one single technological field (i.e., mechanical and aeronautical engineering) for the entire study, although we constrain ourselves in terms of number of observations.

Furthermore, the *h*-index successfully addresses the main disadvantages of other bibliometric indicators such as total number of papers or total number of citations. The *h*-index is much less affected by methodological papers proposing successful new techniques, methods or approximations, which can be extremely highly cited. It also distinguishes truly influential (in terms of citations) scientists from those who simply publish many papers. Therefore it provides a metric of both quality and sustainability of scientific output.

We go one step further and hypothesize that *h*-index can indeed serve as a good proxy variable for an individual's academic reputation, which is nothing but an indicator of regard by one's peers and others. We base our hypotheses on the findings of Hamermesh and Khan (2009). Using data for academic economists, they conclude that, conditional on its impact, the quantity of output (i.e., number for publications in SSCI journals) has no or even a negative effect on reputation. They also indicate that a scholar's most influential work provides only very little enhancement in terms of his reputation, and quality ranking matters more than absolute quality. Consequently, *h*-index would indeed serve as a good proxy for reputation.

This discussion can further be elaborated by plotting scatters of *h*-index versus number of SCI journal publications (see Fig. 3) and *h*-index versus number of citations (see Fig. 4). Notably there exists correlation between these variables to a certain extent. For example the correlation coefficient between the *h*-index array and number of SCI publications array is 0.86, similarly the correlation coefficient between *h*-index and number of citations is 0.72. However, in the citations numbers can vary by almost two orders of magnitude across individuals as demonstrated by Fig. 4. This effect is due to some highly cited papers proposing new methodologies. Since Hamermesh and Khan (2009) demonstrate that a scientist's most influential, therefore highly cited paper does not have a strong marginal

Fig. 3 Scatter of *h*-index versus the number of SCI publications

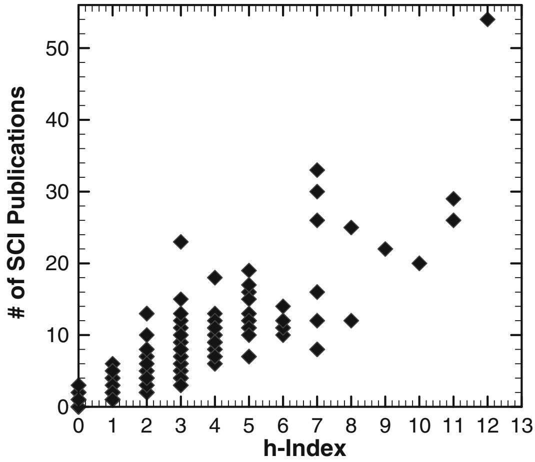
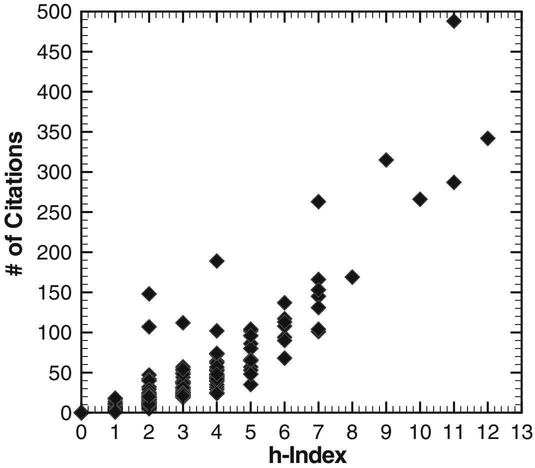


Fig. 4 Scatter of *h*-index versus number of citations



effect on his reputation, our use of the *h*-index as a proxy of apparent scientific effectiveness in lieu of other metrics seems to be well justified.

Even though *h*-index not a perfect measure of one's scientific worth and there exists much criticism against it (Panaretos and Malesios 2009), we share the opinion of Baldock et al. (2009) that no other measure provides a better metric in terms of convenience as per our judgement at least. There exist quite a number of other single figure indicators of academic performance such as the A-index (Jin 2006)and the R-index (Jin et al. 2007) to name a few. Nevertheless, they are not as easily calculted and such calculations require much manual effort. Consequently we have made extensive use of *h*-index in order to compare the effects of academic in-breeding.

Before we proceed with the examination of inbreeding effects on scholarly activity, it would be worth quantifying to what extend it is practiced in each of the higher education institutions that we focus on. For this purpose Fig. 5 demonstrates the percentage of inbred faculty members in each university. According to this figure for example three quarters of YTU faculty members being inbreeds. KTU and follows with approximately two-thirds

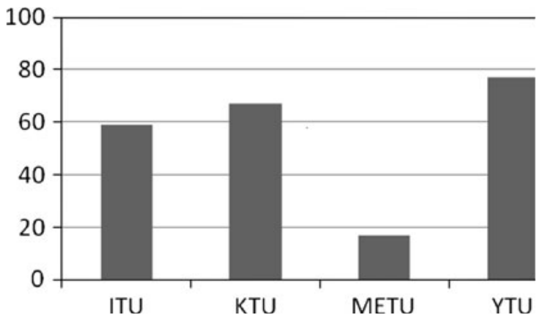


Fig. 5 Percentage of inbred faculty members

each. METU on the other hand seems to have constrained this practice and only one-fifth of its faculty members are inbred. This ratio closely resembles inbreeding ratios in most universities in the United States. Overall ratio of inbreeds within the dataset is 47%.

Before reaching to any conclusion using *h*-index data, it would nevertheless be worth examining its statistical distribution amongst individuals. Figure 6 visualizes this frequency distribution. Note that, almost a quarter of academics in the dataset, have an *h*-index of zero. This means either they do not have any publication in the SCI or they did not receive a single citation to their publications. Furthermore there is a sharp drop in frequency after $h \geq 4$. The mean *h*-index is 2.4 for the whole dataset. The next step in our analysis would be to disaggregate this information and separate out the inbred and the non-inbred individuals from one another.

When we perform this disaggregation according to the inbreeding criterion, then the following picture (see Fig. 7) emerges. The preceding figure (see Fig. 6) is indeed nothing but a kind of merging of Fig. 7a and b. Both distributions look alike however, one observes a significant shift towards the right hand side (higher *h*-index) from the histogram of inbreeds to the histogram of non-inbreeds. The mean *h*-index for inbreeds is 2.1, whereas it is 2.8 for non-inbreeds. Therefore the *h*-index of non-inbreeds is approximately 35% higher than their inbreed colleagues on the average.

Having made this key observation on the dataset, it is now possible to further elaborate and disaggregate the data at the school level. Consequently this time we consider inbred

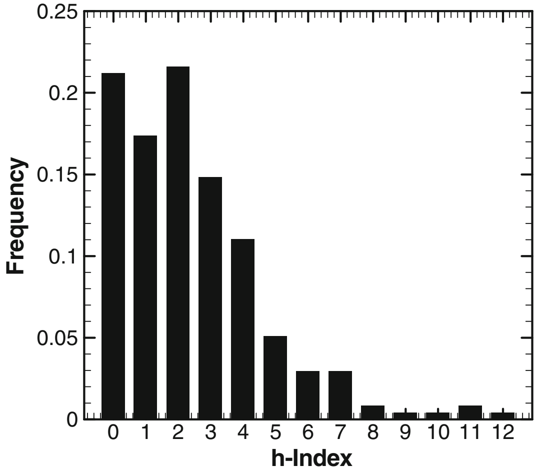


Fig. 6 Histogram of *h*-index distribution for the whole dataset

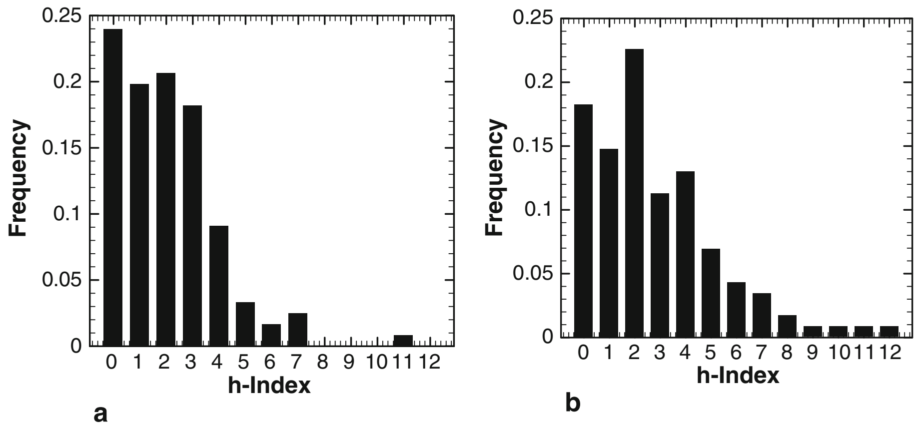
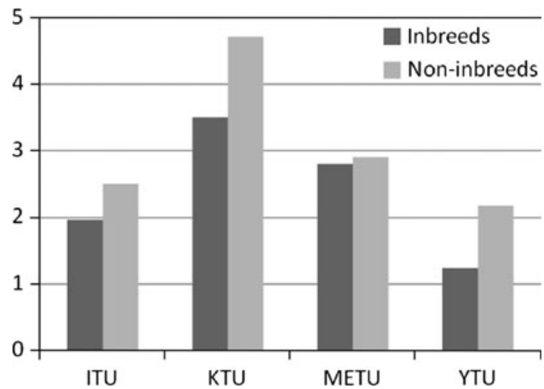


Fig. 7 *h*-index distributions for **a** inbreed and **b** non-inbreed

and non-inbred individuals across four universities. Therefore we now have eight different subsets. Due to the decreased number of individuals within each subset it is not anymore possible to examine frequency distributions; however there is still some meaningful information that can be recovered from the averages. Nevertheless caution must be practiced before reaching to any conclusions when comparing subsets (i.e., inbred vs. non-inbred) to one another, especially should one of these does not contain an enough number of observations to yield a statistically meaningful average. Results are provided in Fig. 8. In each of these four schools mean *h*-index of inbred and non-inbred individuals are plotted. Only in the case of METU the averages for these two groups are almost equal to the degree of uncertainty. However, for the remaining three, there exists a significant difference between inbred and non-inbred. METU case appears to be an exception. Also for this case the percentage of in-bred academicians is only around 20%. This figure is significantly lower than the other three schools. This situation in METU might point out to two different possible causes. First and foremost it might point to the strength of the PhD program, but also it might point out to the fact that in cases where the ratio of in-bred individuals is below a threshold either their selection is made according to more stringent merit criteria or these individuals themselves are forced to catch upon with the rest of the

Fig. 8 Comparison of mean *h*-index for inbred and non-inbred for different universities



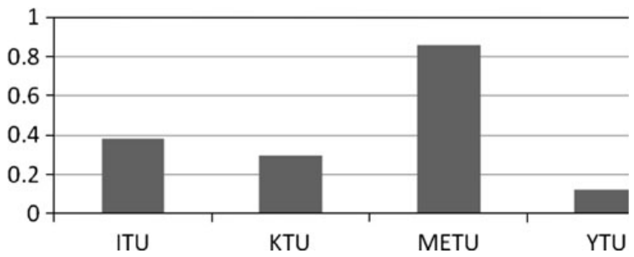


Fig. 9 Comparison of average number of research projects per faculty member

crowd. It our subjective opinion that the second possible explanation is more plausible, since KTU inbred individuals appear to be more productive than METU in-breeds. Aside from this exception there is unanimous agreement that non-inbred academicians are almost 35% more effective than their inbred colleagues in terms of scientific productivity as indicated by the *h*-index. Moreover, there is one more striking detail in this figure, the ratio between non-inbred effectiveness to inbred effectiveness tends to be even higher in schools where in breeding is heavily practiced as clearly indicated by the two extremes; namely METU and YTU. The gap between inbred and non-inbred seems to close when this flawed practice is limited to a possible minimum.

We also look at project management data obtained from the Turkish Scientific and Technical Research Council (TÜBİTAK) in order to reach useful conclusions. Results show that 84.5% of all inbreeds have no projects to manage and only 12.5% have one single scientific project, remaining individuals have more than one project to manage. On the contrary, 56.4% of non-inbreeds have no project management experience, 28.1% have managed one project, 9.0% two, 5.1% three and the remaining individuals have more than three. These findings point out that academically inbred individuals have less scientific project management experience. This in turn also affects their publication performance as indicated by prior discussion.

The negative correlation between Figs. 5 and 9 is indeed quite noteworthy. This indicates that in departments where academic inbreeding is popular, there are not as many scientific projects managed on a per capita basis. This detail is strikingly important, because it clearly points out to academic stagnancy, thus verifying a key argument of inbreeding opponents.

Estimation and results

Utilizing data from four technical universities' mechanical and aerospace engineering departments in Turkey, this study examines the relation between academic productivity and being an inbred faculty member by using the negative binomial regression technique. This dataset is an example of count data. According to Greene (2003), in principle, this type of data can be analyzed by using multiple linear regression; however, the preponderance of zeros and small values and the discrete nature of the dependent variable all suggest that another model with a specification that accounts for these characteristics can be used. Although ordinary least squares (OLS) model generates significant results, highly dispersed data analyses with OLS are generally inconsistent, biased and inefficient (Long and Freese 2003).

Poisson regression model is the one that is widely used for the analysis of count data. Negative binomial model is derived by Greenwood and Yule (1920), and it constitutes to the standard generalized form of the Poisson model. Poisson model has been criticized due to its implicit assumption that the variance of dependent variable is equal to its mean value (Greene 2003). This is referred to as the equidispersion property. Yet this property is violated by the data set used in this study. When the variance exceeds the mean value, this situation on the other hand is referred to as the overdispersion property (Long 1997). According to Cameron and Trivedi (1998), estimates of a Poisson regression model for overdispersed data are unbiased yet inefficient. When data is overdispersed (i.e., the variance exceeds the mean), the Poisson model generates underestimated standard errors, highly significant regression parameters and due to this inaccurate inferences.

Furthermore, the Poisson model would also prove to be problematic should the individuals in the data set initially have the same probability of an event occurring, but the probability changes as the event occur. For example the probability of publishing a third article might be higher when the first one or two articles are published. Negative binomial model relaxes the equidispersion assumption and handles situations where the Poisson model is a poor fit.

In order to determine the model, descriptive analyses were conducted and, we observe that dependent variable (*h*-index) indicates a tendency towards overdispersion with the variance 5.032, and the respective mean value of 2.430. Therefore the negative binomial model is chosen for the analysis. From this model we explore *h*-index relationship with whether the faculty member is inbred or not, the ratio of inbred to non-inbred within the department. This ratio is calculated for each department (i.e., institution) and rank specific in order to control institutional and rank-specific heterogeneity,[2] and dummy variables for associate professors and full professors. Negative binomial model assumes each subject in data set has the same length of observation time. If this issue is neglected, regression estimates would be biased. However, in our data set professional ages of individuals are not equal. In order to alleviate this problem, the model is adjusted to account for the varying length of observation time per individual by using "number of years in academia (i.e., professional age)" as an exposure time variable. The results are summarized in Table 2.

Results are presented both in terms of coefficient estimates and "incidence rate ratios" (IRR). IRR represents the ratio of the counts predicted by the model when the variable of interest is one unit above its mean while the other variables at their mean values and enables one to arrive at a more clear interpretation of the results (Knetter and Prusa 2003).

The first column of Table 2 reports the negative binomial model regression coefficients. Coefficient estimates can be examined for both sign and significance. All estimates have the expected signs. Notably, "inbreeding" variable has a negative sign and significant at the 1% level indicating that, being an inbred faculty is associated with lower *h*-index values. Results also show that higher inbreeding ratios within the department lead to lower *h*-index and this variable is significant at 5% level. This result points out to the fact that in departments where inbreeding is practiced to a high degree, the overall research environment becomes stagnant and as a result of this academic fossilization the scientific throughput of every individual is affected even if the faculty member is recruited from outside (i.e., non-inbred).

[2] Model is estimated also by using only rank specific, only department specific and non-specific (pooled data).

Table 2 Effects on the mean *h*-index negative binomial regression

	h-index	IRR
Inbreeding	−2.169*** (−5.49)	0.114***
Inbreeding ratio in department	−2.615** (−2.41)	0.137**
Associate Professors	−4.057** (−2.43)	0.170**
Professors	−10.612*** (−12.79)	0.000***
Constant	−6.589*** (−6.80)	
Number of observations	226	
Pseudo R^2	0.10	
χ^2 statistics	155.41 (p value = 0.00)	
Likelihood ratio test of $\alpha = 0$	2810.33 (p value = 0.00)	

Values in the parentheses are z-values of the estimates

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

In addition to these, according to the results obtained from our dataset, when the model is adjusted to account for the varying length of observation time per individual by using "number of years in academia", both associate and full professors are associated with lower *h*-index compared to assistant professors. This can be explained by the decrease of scientists' productivities towards the end of their scientific careers.

We also report chi-square statistics and likelihood ratio test for the parameter alpha. According to chi-square statistics the model is significant as a whole. Furthermore, significant likelihood ratio test indicates that for our data, the negative binomial regression model fits better than the Poisson model.

In this model we mainly aim to explore the effect of the practice of academic inbreeding on scientific productivity as quantified by the *h*-index. For the ease of interpretation, we also report IRR results in the second column of Table 2. Estimated rate ratio comparing non-inbred vs. inbred faculty holding the other variables constant. The IRR for variable "inbreeding" is estimated at 0.11 and this ratio tells us holding all the other factors constant, for the inbred faculty, the *h*-index is about 89% lower when compared to the non-inbred faculty.

Further exploring the data we observe that the mean professional age is 19.1 years for the inbred faculty members. On the other hand, for the non-inbred faculty members the mean professional age is significantly lower with 14.3 years. Since inbred faculty members have a longer professional career in comparison to non-inbred faculty members their *h*-index scores are somewhat flattered.[3] Note that *h*-index favors people with longer careers and people who are at the beginning of their professional careers are at a disadvantage. This observation could explain the difference between the numbers such as 89% (as suggested by the regression analysis) or 35% (the difference between arithmetic averages of *h*-index scores). The result from the regression analysis is more reliable

[3] We would like to acknowledge the anonymous reviewer for pointing out this issue.

since the exposure variable (i.e., professional age) takes care of unequal observation times.

Conclusion

An empirical study on the scientific effectiveness of academic inbreeding is carried out utilizing data from Turkish Technical Universities. Results indicate that academic inbreeding adversely affects scientific productivity and effectiveness. On the average non-inbreeds have 35% higher h-indices compared to inbreeds. However, this figure is only the arithmetic average. Inbred faculty members have a longer average career compared to non-inbreeds by almost 5 years. So there is a bias in favor of inbreeds, due to unequal observation times. In addition, non-inbreeds tend to have less scientific project management experience in comparison to their non-inbreed colleagues. One might say that the stagnant research environment adversely affects also the non-inbreeds. This especially has important ramifications regarding the "reverse brain emigration" policies. In order to increase a university's or a department's scientific effectiveness in order to climb up in the rankings, hiring bright individuals would not suffice alone.

In order to test the effect of inbreeding on scientific productivity with the data collected from universities, a negative binomial model is used. In this model *h*-index was used to quantify academic effectiveness. In order to correct for the aforementioned bias due to unequal observation times, professional age is used as an exposure variable. It is found that this model is significant as a whole. According to the results, holding all factors constant inbred faculty members have 89% lower *h*-index values compared to their non-breed colleagues. Also note that the "inbreeding" variable is significant at the 1% level. These are quite remarkable observation demonstrating the negative effects of this practice.

By looking at the figures and tables, it so appears that, should an under-achiever does not get promoted, than the system is already meritocratic. This however is true only to a certain extent. A large number of PhDs from very reputable universities do not get hired in the very first place just because they have not obtained their degrees from the institution looking to hire new people. There always appears to be favoritism for a university's own doctoral graduates when it comes to hiring new faculty members. Furthermore, available faculty positions are indeed a scarce commodity and the faculty search process has to be meritocratic in the very first place, to set the initial conditions right.

Nevertheless, a vibrant research environment by itself does not require that all faculty members publish in archival journals and receive citations as a consequence. Obviously there is more to it and this whole debate is well beyond the scope of this work. Furthermore, one might not overlook the importance of community work that might be performed by faculty members. Quality of teaching is yet another aspect, which has been focused on here since only research productivity is examined. However, authors believe that on the average (in terms of faculty member scientific productivity) major research universities (such as the ones under examination here for the Turkish case) have to be able to cross a certain threshold, in order to compete with the top institutions in the global scale. This can only happen through innovation, which by its very definition requires research.

To sum up, in order to alleviate the negative impacts of academic inbreeding, university administrators must therefore cast the widest possible net during job searches in order to assemble the best qualified faculty members. They should keep their positions accessible to a wider talent pool including researchers from overseas and foreign nationals if possible. If this is not possible legal reforms might be made by the legislature enabling this. The final selection should solely and solely be on a merit basis. The fact that that academic inbreeding promotes stagnancy even in leading research universities as pointed out by Horta et al. (2010), since it tends to lock in place ideas and mentality that persist even after becoming obsolete, should never be overlooked. Our findings regarding scientific effectiveness also point in the very same direction. Also according to our findings, the gap between inbred and non-inbred seems to close when its practice is limited to a possible minimum.

It should never be forgotten that universities play a central role in an innovation-driven modern market economy. Consequently it is not only in the best interest of university administrators to increase scholarly output, but also it is also in the best interest of the society as a whole. Moreover, since public schools spend tax money, it should not be forgotten that their administrators have liability in this regard. Taxpayer liability is ultimately the basis of a modern welfare economy.

Unquestionable academic job security even for people who could not obtain their tenure for years to come needs to be questioned as these stagnant individuals continue to occupy posts even in leading universities. This finally leads to an inferior resource allocation and sub-optimal solutions in terms of human capital allocation. This very situation will in turn adversely affect the economy as a whole, because the sub-optimally allocated human capital consists of the most highly educated/highly productive individuals. The art of economics after all is nothing but to find the balance between scarce resources and unrelenting desires. This time the highly educated human capital is indeed the scarce resource and academic inbreeding leads to the inefficient use of this resource.

In this work we only identify the differences between Turkish universities by spotting the differences between individuals and also between departments. Yet only mechanical/aerospace engineering departments are considered. Expanding the database would of course help in order to assess the general level of scientific productivity. This task shall be quite labor intensive since data collection is mostly performed manually and careful examination is needed. Nevertheless, this is an issue that we are looking into and would very much like to do for prospective studies.

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