*Exploring the Micro, Meso and Macro*
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# ASSESSING THE EFFECT OF MASSIVE ONLINE OPEN COURSES AS REMEDIAL COURSES IN HIGHER EDUCATION

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## Motivation, research question and background

Massive Online Open Courses (MOOCs) are one of the main important trends for the higher education worldwide. The relevance of this new tool for digital learning is related with its major features: (a) courses are "massive" (i.e. allowing scalability), (b) open to everyone interested in a topic, and (c) available online just thanks to an internet connection and a digital device. MOOCs are then an example of "disruptive innovation" that could revolutionize education as we know (Christensen & Eyring, 2011). The benefits related to MOOCs concern both efficiency and quality of education service. Universities engage with MOOCs seeking to increase their visibility, recruit new students (Hollands & Tirthali, 2014), provide flexibility of learning outcomes, improve campus teaching and respond to the evolving needs of learners worldwide. Effectively, MOOCs can have a wide range of impacts on Higher Education institutions, encompassing marketing facilitation (Riddle, 2012), stakeholder inclusiveness through democratization of education (Jorge et al. 2015), new university structure, as well as day-to-day operations improvements. Furthermore, MOOCs allow academic institutions to decrease their cost structure: lower costs can be reached through the reduction in facilities expenses (Bacow et al. 2012). Focusing on students' benefit introduced by MOOCs, we can observe that, starting from lower levels of education, MOOCs help students to prepare for a school/university enrolment test or a school/university exam, providing a higher flexibility and a higher quality of preparation. In this respect, MOOCs can boost students' motivation, employing several ways of supporting the learning process (Jorge et al. 2015).

The present research moves from this point focusing on the MOOC platform developed by Politecnico di Milano, the first Italian university to develop its own portal: POK (PoliMi Open Knowledge). This online platform has its own unique strategy: not as a substitute to traditional education but as a *support*, by facilitating, or actually *bridging*, the transitions at key stages of the educational path – from high school to university, from bachelor to master degree, from university to the work environment: "MOOCs to bridge the gaps" (Politecnico di Milano, 2015). In this perspective, the main aim of these MOOCs is to level the playing field between students who have very different educational background – for being able to attend the courses at PoliMi with the best auspices. The case of Politecnico di Milano represents a significant opportunity of research, thanks to its explicit strategy in developing MOOCs. Furthermore, a considerable benefit of focusing the research on POK platform is the availability of a large number of data concerning, not only POK users, but also all Politecnico di Milano students. In the context of the MOOCs offer provided by Politecnico di Milano through its platform POK, this study wants to examine the two following research question:

- Which are the effects of using MOOC on the students' subsequent academic performances, after taking into account their individual characteristics?

We focus on the students enrolled in three different MOOCs types, one of "From Bachelor's to Master" (FinAccount101), the other of "From High School to University" (MAT101, FIS101 and FIS102) – the reason of the choice stems from the direct relationship between these MOOCs and subsequent PoliMi's courses taken by students. From strategical point of view, Politecnico di Milano developed POK (PoliMi Open Knowledge) following three main objectives: (a) meet a diversity of learners' needs; (b) introduce scientific culture to citizens; (c) support new forms of teaching and learning and their integration to enhance curricular education at Politecnico di Milano (PoliMi Open Knowledge, 2015). The idea of the proponents is to provide materials that can *align* the basic competences of prospective students to the knowledge that is assumed to be acquired before taking the courses at PoliMi (as, for instance, basic competences in physics and mathematics). From a technological perspective, the POK platform is a personalized version of Open EdX, the open source platform of EdX, which has been made available to other institutions since June 2013. On June 3rd, 2014 the first three POK courses went online. The results, after the first year, were very encouraging in terms of participation: 22,900 total of MOOC participants, 15,400 users enrolled in POK platform and 10 MOOCs online. Now, after almost two years, the MOOCs available are 15 (fifteen) and users enrolled are approximately 24,000 (PoliMi Open Knowledge, 2015).

## Theoretical framework and hypotheses of the research

The second research question deals with the measurement of the effects of using MOOCs on subsequent exams taken in corresponding disciplines. Our purpose is to offer an empirical analysis, not only of the impact on the MOOCs' performances (i.e. the success of the POK initiative), but also on the academic performances of students, who use POK as a support for the preparation in a specific subsequent academic course. According to the Politecnico di Milano's strategy of POK delivery, we expect to find a positive correlation between using MOOCs and the students' performances in the academic course, concerning the same topic developed in MOOC. Although Greene et al. (2015) found empirical evidence that the factor "MOOC supports academic current program" has a significant negative effect on MOOCs achievements; we think that the evidences for POK could generate the opposite results, thanks to its unique strategy of dealing with an alignment of competences at the beginning of academic courses. Specifically, POK courses have the main aim of aligning entry-level competences across students who have a different educational background. It can then be the case that the main beneficial effect can be concentrated on those students who lack the basic competences in core subjects, and can fill their gaps through MOOCs, being able to pass subsequent first-year exams even if they do not have strong experiences in secondary education on related disciplines. Hence, our hypothesis is:


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- Hypothesis: Students who attend a POK course do obtain higher performances (i.e. higher grades) in discipline-related courses that they attend in their subsequent studies at Politecnico di Milano (both bachelor and master courses), when compared with their similar counterparts who did not attend the corresponding POK course.

## Data and methodology

In order to investigate the possible effect that completing a MOOC (i.e. obtaining the final certificate), has on the ability of a student to succeed in a discipline-related exam, we now take into consideration POK users who are enrolled at PoliMi. Moreover, we focus our attention on four MOOCs whose relationship with an academic exam is evident, namely:

- MAT101, which is presented on POK in the cluster "From high school to university" and is related to the exam of Mathematical Analysis and Geometry;
- FIS101 and FIS102, both contained in the cluster "From high school to university" and related to the exam of Physics;
- FINACCOUNT101, part of the cluster "From bachelor to master" and directly related to the exam of Accounting Finance and Control (AFC).

Mathematical Analysis, Geometry and Physics are part of the study plan of all bachelor degrees in Engineering at PoliMi. Accounting finance and control is part of the study plan in Management Engineering (master degree). For this reason, we consider two populations of PoliMi students in this last part of the paper:

- Students who enrolled in 2014/15 Academic Year in a bachelor degree in Engineering (N=5,928);
- Students who enrolled in 2014/15 Academic Year in a master degree in Management Engineering (N=663).

Only a subgroup of students enrolled in one of the MOOCs previously cited: they are 1,329 for Mathematics, 1,251 for Physics and 101 for AFC. As a last step, we consider the subgroup that obtained the final certificate of the MOOC, that is a score in the final test higher than 0.6 (Figure 1 summarizes the sample selection).

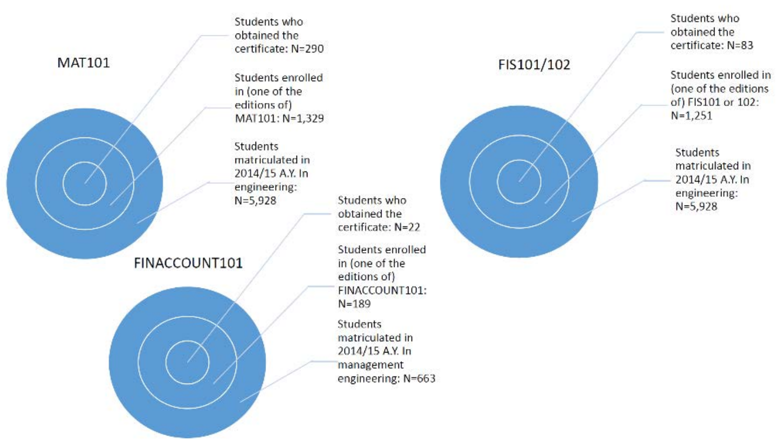


Figure 1. Sample size and selection


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Starting from the original population of students, we define two possible “treatments”; the first option is obtaining the final certificate in the related MOOC, the second option include a higher number of possible treated students, defining the treatment as being *active* in the related MOOC. By *active* we mean the same stated in previous paragraphs: obtaining a final score higher than 0.1. This means that the student has at least started the final test or one of the intermediate test, having an interaction with the platform other than the pure enrolment in the MOOC. In our data, this treatment is expressed through a binary variable (Di) equal to 1 when the student $i$ is treated, and 0 otherwise. The underneath assumption is that finalizing the MOOC would have a positive/negative effect on the ability of the student to obtain a higher score/pass the discipline-related exam, which is our outcome variable. To investigate this issue, we apply a propensity score matching approach, where the treatment effect T for a student i can be expressed as

$$T_i = Y_i(1) - Y_i(0) \quad (1)$$

where $Y_i(D_i)$ is the potential outcome, given the treatment $D_i$. The final parameter of interest, defined as the “average treatment effect on the treated” (ATT) is then defined as

$$T_{ATT} = E[Y(1)|D = 1] - E[Y(0)|D = 1] \quad (2)$$

In this paper, we propose two possible outcomes $Y_i$. The first is a dummy variable equal to 1 when the student passed the exam and 0 otherwise; in this sense, the effect of the treatment can be read as the effect on the probability to pass the exam. The second outcome is the grade obtained by the student; it varies from 18 (the sufficiency) to 30 when the student passed the exam, and is missing when he/she did not. It is worth to stress that the three exams are considered separately, so that three propensity score matching models are actually run. Propensity scores are defined through a probit regression where the dependent variable is obtaining the certificate/being active in the MOOC (dummy = 1) or not (dummy = 0). To estimate this parameter, we include a vector of student’s personal characteristics (X1) and information about his/her university career (X2). Computing the propensity scores through this methodology, we aim at including as many observable individual characteristics as possible, so that the matching procedure allows the comparison of students that only differ in their exposition to treatment.

$$D_i = \alpha_0 + \alpha_1 \bar{X}_{1_i} + \alpha_2 \bar{X}_{2_i} + \varepsilon_i \quad (3)$$

Among individual characteristics we consider gender, citizenship, Region of residency (if the student is resident in Lombardy Region, where PoliMi is located, or not) and the socio-economic status. About the university career we take into consideration if the student obtained a scholarship, the average grade obtained in his/her career and the amount of university credits. Moreover, for master’s students we consider if the student obtained the bachelor degree at PoliMi or not and if he/she is a supplementary year student, which refers to student who took more time than generally expected to complete the bachelor’s degree. For bachelor’s students


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we consider the high school grade and if he/she obtained a diploma with a major in scientific disciplines (called *liceo scientifico* in Italy); finally, we take into consideration if the student obtained an OFA, attributed to students who had to repeat the admission exam at PoliMi because they did not reach the minimum score in Physics or Mathematics.

## Empirical results

At first, treatment is defined as obtaining the certificate in the related MOOC. From a descriptive point of view, some characteristics are statistically different between treated and control groups. A higher percentage of female students obtained the certificate of Mathematical Analysis and Physics (33% and 31%, respectively); treated students tend to have a higher exam average and more credits by course attended in their university career, indicating a higher relative performance at university. They also register a higher grade from high school, referring to higher level of competencies at their entrance at university (for bachelor students). Though, when focusing on the level of entrance competencies in Mathematics and Physics, there appears to be a lack of matching with PoliMi requirements, given the higher number of students who obtained an OFA (i.e. a formative 'debt' assigned to students who did not pass the Mathematics of the Physics section of the admission exam). Looking at panel B, the significant characteristics in the estimation of the propensity scores are those related to the university career (average exam grade) and high school career (high school grade), both positively related to the probability to obtain the certificate in Mathematics and Physics. In other terms, the higher the average grade, the higher the probability to complete the related MOOC. Moreover, being a female student and having had an OFA are both positively related to the probability to obtain the certificate in Analysis (in the latter case, stressing the role of MOOC courses in filling a competence gap).

In order to have a closer look at the phenomenon, we also define a second possible treatment, which is defined as being active in the related MOOC (as discussed above, by active we mean a student obtaining a final score higher then 0.1). From this point of view, results show a pattern that follows the previous one. In this case, the effect is not significant, but negatively related to the student's grade. We can interpret the negative treatment effect on exam grade in the light of the *recovering* (*aligning*) role of MOOCs. In this interpretation, students who attend MOOCs are those who would have obtained lower grades also in absence of treatment. Though, attending a MOOC has a positive effect on their ability to pass the exam. In other terms, this is due to the effect of the MOOC that help students with a lack of initial competencies to pass the MOOC-related exam, though obtaining lower grades than the average. To test this hypothesis, we consider those students who have been defined as active in each MOOC, comparing them to all the other students matriculated in the same year. Among them, we look at those who can be defined low-achieving since their entrance at PoliMi. This definition is based on the high school grade for Mathematical Analysis and Physics, and on the bachelor grade for AFC. We define students with a lack of initial competencies those who obtained a high school grade lower than 70 up to 100 (60 is the sufficiency); for master students, this definition is reserved for those whose bachelor grade is lower than 90 up to 110. Finally, among those students who are low achieving, we compare the proportion of them who were also able to pass the MOOC-related


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exam. The students who passed the exam of Mathematical Analysis and were labelled as active in the related MOOC are 30% of low achieving students, while the proportion is 26% for students that did not take part in the MOOC. Similarly, the percentage is 44% in Physics, versus 36% among similar students not active or not enrolled in the MOOC. Finally, the percentage is 100% for AFC, as it is 87% for all other students. The higher percentage of low achieving students able to pass the exam, given their participation in the discipline-related MOOC, support the hypothesis that MOOCs are actually used by students to "close the gap" in a specific discipline. This helps them to increase the possibility to pass the exam, even though with averagely lower scores. In order to check this last hypothesis, we run the propensity score matching only considering the group of students who have a lack of competencies in core subjects. Results from Table 1 show that this is actually the case, with all the test scores higher for the treated group than for the control one, though not significant. Looking at the increase in the probability of passing the exam, we can actually see a significant effect in Mathematical Analysis: among students with a lack of initial competencies, those who attended the MOOC in mathematics obtain a 15% increase in the probability to pass the exam than their comparable counterparts who did not – and, this effect is statistically significant.

Table 1: Propensity score matching, treatment: *being active in the MOOC* subgroup of students who lack of initial competencies

Panel A. Descriptive statistics

| Variable | | Mathematical Analysis | | Physics | | AFC | |
|---|---|---|---|---|---|---|---|
| | | Treated N=113 | Control N=901 | Treated N=16 | Control N=998 | Treated N=9 | Control N=105 |
| Female student (dummy=1) | Mean | 0.21* | 0.09* | 0.06 | 0.11 | 0.33 | 0.29 |
| | *Std Dev* | *0.41* | *0.30* | *0.25* | *0.31* | *0.50* | *0.45* |
| Italian citizen (dummy=1) | Mean | 0.76* | 0.91* | 0.75* | 0.90* | 1.00 | 0.99 |
| | *Std Dev* | *0.43* | *0.27* | *0.45* | *0.30* | *0.00* | *0.10* |
| Lombardy Region resident (dummy=1) | Mean | 0.74* | 0.81* | 0.62* | 0.80* | 0.78 | 0.70 |
| | *Std Dev* | *0.44* | *0.39* | *0.50* | *0.40* | *0.44* | *0.46* |
| Socio-economic status (discrete variable from 1 to 10) | Mean | 5.81 | 6.25 | 6.19 | 6.20 | 5.33* | 7.34* |
| | *Std Dev* | *3.16* | *2.99* | *3.04* | *3.01* | *2.00* | *2.83* |
| Scholarship awared (dummy=1) | Mean | 0.02 | 0.02 | 0.06 | 0.02 | 0.00 | 0.06 |
| | *Std Dev* | *0.13* | *0.15* | *0.25* | *0.15* | *0.00* | *0.23* |
| Average exams grade (up to 30) | Mean | 22.09 | 21.90 | 23.06* | 21.90* | 26.50 | 25.89 |
| | *Std Dev* | *2.31* | *2.29* | *2.66* | *2.28* | *1.54* | *1.29* |
| Credits amount (in the career) | Mean | 42.35 | 44.10 | 50.69 | 43.79 | 70.00 | 69.29 |
| | *Std Dev* | *28.35* | *29.23* | *27.94* | *29.14* | *16.77* | *17.20* |
| Scientific high school diploma (dummy=1) | Mean | 0.46* | 0.72* | 0.50 | 0.70 | | |
| | *Std Dev* | *0.50* | *0.45* | *0.52* | *0.46* | | |
| High school grade (up to 100) | Mean | 65.03 | 65.57 | 64.13 | 65.53 | | |
| | *Std Dev* | *3.79* | *3.55* | *4.03* | *3.57* | | |
| OFA student (dummy=1) | Mean | 0.39* | 0.14* | 0.19 | 0.17 | | |
| | *Std Dev* | *0.49* | *0.35* | *0.40* | *0.38* | | |
| Supplementary year student (dummy=1) | Mean | | | | | 0.00 | 0.02 |
| | *Std Dev* | | | | | *0.00* | *0.14* |
| PoliMi bachelor degree (dummy=1) | Mean | | | | | 1.00 | 1.00 |
| | *Std Dev* | | | | | *0.00* | *0.00* |

Note: * p<0.1, Ha: difference between treated and control groups != 0.


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Panel B. Treatment effect

| Subject | Output | #Untreated | #Treated | Sample | Treated | Controls | Difference | S.E | T-stat |
|---|---|---|---|---|---|---|---|---|---|
| Mathematical Analysis | Grade obtained ∈ [18;30] | 228 | 34 | Unmatched | 22.40 | 21.08 | 1.30 | 0.525 | 2.48 |
| | | | | ATT | 22.40 | 21.94 | 0.44 | 0.441 | 0.55 |
| | Having passed the exam ∈ [0;1] | 651 | 80 | Unmatched | 0.43 | 0.35 | 0.07 | 0.057 | 1.32 |
| | | | | ATT | 0.43 | 0.28 | 0.15 | 0.075 | 2.00 |
| Physics | Grade obtained ∈ [18;30] | 356 | 7 | Unmatched | 23.29 | 21.45 | 1.83 | 1.199 | 1.53 |
| | | | | ATT | 23.29 | 21.71 | 1.57 | 2.132 | 0.74 |
| | Having passed the exam ∈ [0;1] | 718 | 13 | Unmatched | 0.54 | 0.50 | 0.04 | 0.140 | 0.3 |
| | | | | ATT | 0.54 | 0.69 | -0.15 | 0.196 | -0.78 |
| AFC | Grade obtained ∈ [18;30] | 91 | 9 | Unmatched | 25.33 | 24.97 | 0.37 | 0.724 | 0.51 |
| | | | | ATT | 25.33 | 24.67 | 1.07 | 1.067 | 0.62 |

Note: Number of treated and untreated students refer to those on common support.
A student is "active" when the final grade is higher than 0.1. Socio-economic status is measured by the fee level. Credits amount refers to the number of credits by courses attended since the students' enrolment. OFA students are those who showed a lack of core competences in the admission exam. Supplementary year students are those who took more time then theoretically expected to complete the degree.

## Concluding remarks

The current paper considers the empirical experience of an Italian technical university providing MOOCs. In line with the initial hypothesis, results show a potential effect of these courses to bridge students' gaps. A causal approach is adopted to estimate the effect of attending MOOCs on students' subsequent achievement by means of a propensity score matching approach. Results show a heterogeneity of the effect, which is not overall significant. Though, when attention is focused on students with a lack of initial competencies (in terms of grade in the lower level of education), the effect of attending MOOC is positive and significant for mathematical analysis. This result can be interpreted as a partial alignment between institutional strategy – MOOCs to bridge the gaps – and performances observed. Hence, it is particularly important for higher education institutions to formalise objectives and strategies for digital learning, in order to be able to target efforts accordingly and assess the level of accomplishment.

Further research should include a new wave of data, in order to make estimations more robust and test for the persistence of the effects over time. Moreover, empirical data should be supported by means of interviews made to students – to check their level of satisfaction with the course attended and catch their motivation and engagement – and with lecturers – to investigate the strengths and weaknesses of their course design strategy.

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