Is the gender gap narrowing in higher education computing studies?

The case of Norway, Spain and Tunisia

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***Title*— Is the gender gap narrowing in higher education computing studies?**

***Abstract*— Traditionally, women have been underrepresented in Computing studies. The discipline is male-dominated in spite of the efforts promoting the participation of women in the field, both in the student base and in the professional arena. Literature underlined that student attraction and professional retention are aspects to analyse in a sound way in order to build strong and grounded theories for this complex misbalance phenomenon. In this scenario, authors study the gender gap in computing education by collecting data such as female students enrolled in one of the mandatory courses and female members of faculty. In addition to this data, socio-economic factors such as Gross Domestic Product (GDP) and unemployment rate of the countries under study were considered. Results show that the gender gap in computing studies is not narrowing significantly despite the measures that were undertaken. In an attempt to explain the gender gap by considering macroeconomic variables, authors highlight the complexness of the phenomenon. Authors believe that there is not a single answer or explanation to this imbalance and a variety of aspects from values to culture and from economy to expectations need to be analysed in order to bring answers and possible solutions to this tangible problem.**

***Index Terms*— Gender issues in Computer Science, women in ICT, Gender equality.**

I. Introduction

Computing industry (including software engineering, computer engineering, computer science, information technology and information systems), in spite of the growing efforts towards automation [1], is still quite dependant on talent [2]. Nowadays, industry is facing problems on talent availability. In Europe, around half a million positions in ICT will be vacant by 2020. The roots of this problem are multiple. Thus, and according to a recent study [3], the number of students who graduate each year in careers related to the field of computing studies, is less than half of those entering the studies. In the same report, it is pointed out, outlining the problem more clearly, that computing students take a long time to complete their studies or, in many cases, they enter the work market before finishing their studies.

In Spain, for instance, the Spanish technology and digital sector employer association (AMETIC), in its latest publication available at the time of writing this article [4] indicates that more than half of the digital profile selection processes in Spain are not covered because of the lack of candidates that adapt to the profiles demanded. A panorama of shortage of qualified professionals for the industry in Spain and throughout Europe is drawn, leading to those known as talent wars, an expression coined by Steven Hankin from McKinsey [5].

In this scenario, we found that higher education enrolments in the computing field cannot meet the talent needs of the industry. However, there is a circumstance that would favour a greater flow of professionals to the sector: bridge gender gap in computing studies. It is not difficult to deduce that a greater contribution of women workers in the labour force would relieve the pressure exerted on the market due to the lack of available talent. However, and as we will show later, in general, the contribution of female workers has been gradually decreasing in recent years. This fact does not seem to be caused apparently by the lack of opportunities in the sector, as shown by the demand for talent indicated above.

The problem of lack of balance of study enrolments in Europe has been revealed by a very large set of reports. The last one places the enrolment rate of female computing students in the European Union at 16.7%, according to EUROSTAT [6]. The lack of gender balance in studies related to computing exists in some countries of the Union at rates as modest as 6% in the Netherlands, 8% in Belgium and 10% in Luxembourg. In this geographical environment, the country with the highest proportion of women in studies and the job market is Bulgaria with 33.14% (studies) and 26.50% (job market), followed by Romania with 30.89% and 25.70% respectively.

In the case of employment, the picture is equally unbalanced. In the same report presented by EUROSTAT which has been previously reviewed, it is indicated that 17.2% (8.4 million) of the total workforce in the EU, working on information technologies, are women.

In recent years, there has been a movement that aims to balance the proportion of students and professionals in information technology through a set of interventions. Thus, scientific literature has reported policies and initiatives on the subject such as awarding prizes: “EU Prize for Woman Innovators”, establishing gender-related bodies, agencies and associations [7], and incorporation of gender mainstreaming in research [8]. However, the reality reflects a decrease in the enrolment of women in recent decades and interestingly one of the main reasons behind this lies in introductory computer sciences courses [9].

Moreover, the problem of lack of balance is not new, as reflected pervasively in the literature [10]–[15]. However, in a recent paper [16] based on a tertiary study, three avenues of research are enunciated:

1. Lack of research on the consequences of gender imbalance in the IT profession.

2. Lack of coherent explanation for gender imbalance in the IT profession.
3. Lack of impact of interventions that address gender imbalance in the IT profession.

In this work, the authors address the second of the aspects stated above. From the information that has been collected in a set of countries (Norway, Spain and Tunisia), data from three higher education institutions (Østfold University College, University of the Basque Country and National School of Computer Sciences) are compared in relation to macroeconomic data and international reports. The purpose of the work is, first of all, to compare the data of the three countries as well as their evolution in relation to students and teachers. Secondly, with the comparison of the three cultures, it is intended to prepare a series of observations and reflections on the subject, as well as future work in the field of the gender gap in the computing field.

This paper is an extension of authors` previous work, in which they explore gender diversity and its evolution by comparing data from three different countries in terms of students enrolled in computing studies and faculty members in the field [17]. In addition to this, different socio-economic variables are included in this study because authors believe such variables are beneficial in explaining the existence of the gender gap and the differences between countries in this context.

II. Method

In order to compare the differences that occur between the countries analysed, a set of data that is considered comparable was constructed. Therefore, information was collected about the students from one of the traditional courses of computer studies, Software Engineering in the three selected public universities. This information was obtained in the 2018-2019 academic year by also adding information from the same course in the previous years. In addition, information was collected regarding the composition of the staff of the teachers in the centers where the subject has been taught, without differentiating the professional category of the subjects that make up the faculty.

Authors collected this data by analysing documents of each of the institutions, in addition to the observation technique which is enforced by their extensive teaching experience. In order to shape the authors` perception around the topic, the data collected has been compared with other known reports and resources. The use of diverse data collection techniques ensures triangulation of methods, thus enhancing the validity of this study [18]. Moreover, this work considers a diversity of countries with the goal of exploring the bigger picture of the phenomenon under study [19].

Macroeconomic aspects such as gross domestic product, unemployment data, the quality of life index of the Organization for Economic Cooperation and Development (OECD), the gender equality index and a set of information were added to this dataset in order to complement the data with more explanatory variables.

In a study like this, it is necessary to take into account the threats of validity. The authors consider that external validity is the most important element to be taken into account in the investigation. External validity refers to the generalization of the results in extension and in the form of being extensible to other populations, situations, treatment, and measurement variables. The authors, admit that a very limited number of institutions per country has been measured in countries that have a medium size. However, authors strongly believe that it is important to interpret the gender gap in computing studies based on socio-economic factors. That is why the focus of this study is on a diversity of countries rather than exploring many different institutions in the same country. It is noteworthy that higher education institutions within a country are quite similar in terms of education system and policies undertaken. The diversity of perspectives and contexts (different countries, cultures…) allows the findings of this paper to be generalizable, thus applied to other higher education institutions.

Additionally, the technique of convenience sampling has been used, thus the sample has not been taken randomly, since the data of the institutions in which the researchers provide their services have been used. In any case, the prospective nature of the study presented may justify the sample decision taken by the authors.

III. Countries Analysis

In this chapter, the different institutions that have been part of the study are introduced, including in it and Table 1 the main indicators and data that have been taken into account to carry out the study. The aforementioned table includes percentages per country of women in faculty of the study period 2016-2018, gross domestic product for the three countries, Gender Inequality Index and Gender Development Index data, General and female unemployment rates.

A. Norway

Høgskolen i Østfold (Østfold University College in English) was founded on 1 August 1994 merging five university colleges in the Østfold region. The institution offers a broad range of one-year programmes, bachelor's and master's degree programmes. Currently, Østfold University College offers four bachelor programs in the broad field of computing, namely, Digital Media Production, Computer Engineering, Computer Science and, finally Information Systems. The course Software Engineering is a mandatory course for the latter two bachelor studies. Software Engineering covers 10 European Transfer and Accumulation System (ECTS) credits. It is programmed for the second year of studies of the three that all bachelor programs have in the institution. Data presented in this study is taken from students enrolled in the Software Engineering course.

In average, women are 10.97% of the students in the course in the period of three years that has been considered, whereas men are the remaining 89.03%. The remarkable increase in the number of students, scaling from 38 in 2016 to reach 63 in 2018, is because of the increase of the offer of student positions in the department.

Regarding the gender balance in the faculty at the department of Computer Sciences, currently, 24.32% in the personnel are women (nine out of thirty-seven).

Norway presents a GDP of 62182 $ per capita in 2018

according to OECD, growing around 1.4% in figures. The gross domestic product (GDP) measures the national income and output for a given country's economy.

By May 2019, the unemployment rate was 3.4% of the population according to Statistics Norway [20], males unemployed were 3.6% and females 3.2%.

Gender Inequality Index (GII) is a composite measure reflecting inequality in achievements between women and men in three dimensions: reproductive health, empowerment and the labour market. Promoted by United Nations Development Programme, the higher the GII value the more disparities between females and males and the more loss to human development. Norway is #5 in the ranking of 160 countries in the last report (2017) with a value of 0.048.

The second report included in our study is the Gender Development Index (GDI). The GDI measures gender gaps in human development achievements by accounting for disparities between women and men in three basic dimensions of human development—health, knowledge and living standards. Promoted also by United Nations Development Programme, it shows how much women are lagging behind their male counterparts and how much women need to catch up within each dimension of human development. Norway is leading the ranking of 164 countries with a value of 0.991.

An overview of the two rankings leads to the conclusion that Norway is unquestionably among the most balanced countries in the world.

TABLE I
DATA FOR NORWAY, SPAIN AND TUNISIA

	Norway	**Spain**	**Tunisia**
% female faculty	24.32%	44.08%	64.62%
% female students 2016	15.79%	22.73%	47.09%
% female students 2017	5.56%	13.64%	45.70%
% female students 2018	12.70%	26.32%	50.00%
GDP per capita	62182	39087	3464
Gender Inequality Index (Value)	0.048	0.080	0.298
Gender Inequality Index (Rank)	5	15	63
Gender Development Index (Value)	0.991	0.979	0.897
Gender Development Index (Rank)	1	26	95
General unemployment rate	3.4%	14%	15.5%
Female unemployment rate	3.2.%	15.7%	22.6%
Measures taken to narrow the gender gap	Integrating gender equality policy with the welfare state, the launch of KvinnForsk	Incorporation of gender mainstreaming in research	Governmental reforms, forums such as “The Tunis Forum on Gender Equality”

Norway is implementing a strong set of measures to support gender equality [21]. Several measures integrated with the welfare state, promoting general equality [22] are implemented throughout the country. In spite of these efforts, according to a recent report by EuroStat [23], women in ICT in Norway are by 2017, 19.5% of the employed professionals. Ten years before, it was just 15.3% of the sample. Although numbers are still quite imbalanced, these policies seem to have an impact on gender balance.

Data in Østfold University College is consistent with the official data provided by the country, although there is a need to increase the number of women in studies to reach national average numbers. There is also a need to conduct research on the variances between Norwegian figures and figures at Østfold University College.

With regards to academic members, gender balance is not a fact. Around a quarter of the current department members are female. However, it is important to note that this is doubling the figures of current students. The institution launched back in 2009 *KvinnForsk*, a network that helps individual female researchers in their career inside Østfold University College. *KvinnForsk* was established backed up by the Committee for Gender Balance in Research (Kif Committee). The goal of *KvinnForsk* is to contribute to equality efforts and to promote and retain female scientists at Østfold University College. As a consequence of this, the proportion of women increased from 31 % in 2008 to 44 % in 2012.

B. Spain

University of the Basque Country is a Spanish public higher education institution placed at the Basque Autonomous Community, Spain. The courses catalogue consists of 67 Bachelor´s Degrees, 103 official master programmes, 44 professional & expert diplomas and 71 PhD programmes. In the field of computing, there are two bachelor programs related to software engineering: computer engineering (Gipuzkoa campus), and information systems and management (Bizkaia and Araba campus). Each bachelor program is taught in one of the campuses. The course entitled Enterprise Information Systems is available for the second bachelor during its third year covering 6 ECTS credits. Data is taken from students enrolled in the Enterprise Information Systems course carried out in the Araba campus.

As coded in Table 1, the average number of women are

20.63 % of the students enrolled in the period of three academic years. Numbers are higher than the ones collected in Norway. There are 93 current members in faculty, out of which, 41 of them are women (44.08%). These numbers include all members of the department in all the campuses. These numbers are also higher than the ones collected in Norway.

With regards to macroeconomic data, Spain, according to OECD presents a GDP of 39087$ in 2018. By June 2019, unemployment rate is 14 % of the population according to the *Instituto Nacional de Estadística* [24]. Unemployment rate among women reaches to 15.7% while it is just 12.5% among men. This is a quite important difference. With regards to the unemployment for people under 25, it is 32.4% distributed as follows: 30.8% men and 24.3% woman. It is worth to note that unemployment rate for ICT workers is around 10% according to the *Instituto Nacional de Estadística*.

Regarding the Gender Inequality Index, Spain is #15 in the ranking of 160 countries in the last report (2017) with a value of 0.080. In the Gender Development Index, Spain is #26 in the ranking of 164 countries with a value 0.979.

According to the report issued by EuroStat [23], women in ICT in Spain are by 2017, 16.1% of the labour force. By 2007, they were 18.3% of the sample. In Spain, 85.4% of the workers with ICT studies are men and the remaining 14.6% are women; by 2015 this figure was 16.1% [25]. These are not encouraging figures with regards to the presence of women in the labour market. However, it is also important to note that, being 54.3% of the higher education students in the country, just 7% of the female students choose ICT education. This underlines the decrease of the interest by women in IT in Spain both in studies and in the job market.

Data at University of the Basque Country is consistent with aggregated data in Spain, although is more balanced than national figures. One more time, there is a need to investigate the differences between national figures and numbers at University of the Basque Country.

With regards to faculty, the sample is quite balanced in numbers: 44% of the current department members are female, doubling the figures present in the students' side.

C. Tunisia

The Ecole Nationale des Sciences de l'Informatique, ENSI, (National School of Computer Sciences in English) was established in 1984 at the University of Manouba. It is a Tunisian higher education public school. ENSI offers three types of diploma specialized in computer science: PhD thesis, master's degree and computer engineering degree. The course Software Engineering is a mandatory course for the second year of computer engineering degree studies. It covers 9 ECTS (8% of the training) in ENSI. Data is taken from students enrolled in this mandatory course in this school.

Considering three academic years 2016, 2107 and 2018, in average, women are 47.50% of the ENSI engineering students enrolled in the course, while men are the remaining 52.50 %. Comparing with resulting numbers collected in both Norway and Spain, Tunisia ones are higher which is consistent with the UNESCO Science Report [26]. It is mentioned that while women have achieved parity in life sciences in many countries, they still trail men in engineering and computer sciences. However, among a good number of developing countries, Tunisia is presenting a sizeable proportion and share (41%) of women engineers and computer scientists. In addition, regarding the balance in the faculty in the Computer Sciences department, currently, 64.62 % of the personnel are women. In fact, there are 42 women out of 65 current members.

According to OECD and World Bank National Accounts data [27], Tunisia presents a GDP of 3464$ per capita in 2017. In the third quarter of 2018, unemployment rate in Tunisia is 15.50% of the population according to the national institute of Statistics Tunisia [28], where females unemployed rate was 22.6% and males 12.9% according to world bank data. Regarding the Gender Inequality Index (GII), Tunisia is #63 in the ranking of 160 countries in the last report (2017), with a value of 0.298.

With regards to the Gender Development Index (GDI), Tunisia reaches 0.897. An overview of these two indexes (GII and GDI) leads to the conclusion that Tunisia is trying to implement strategies to establish gender equality and then to be among the balanced countries in the world, however, is still far from the figures of Norway or Spain. However, among the countries of the MENA (Middle East and North Africa) region, Tunisia is implementing many efforts to reach gender equality and it is known to be the leader one [29]. These policies and strategies have borne fruit to narrow the gap between men and women in educational, socioeconomic, cultural and political life which explain the gender balance more or less accomplished of ENSI students. Aligned with that, the government of Tunisia in close collaboration with UNDP, and UN Women and other partners organized the Tunis Forum on Gender Equality which was held on 24–26 April 2019 [30]. This forum was an opportunity to strengthen the mobilisation of partnerships for gender equality and to highlight and discuss opportunities helping and hindering gender equality.

Moreover, in the ICT sector, women are well represented where they account for almost 41% of all workers. Majority of the employees in this sector are female and are university graduates, which is conform to the numbering results of Tunisian higher education institution in question. In fact, with regards to academic members, gender balance is so far as female represent around three quarters of the current department members. Aligned with that, in 2015, women represented 42% of university professors and 40% of tertiary education enrolment [31].

Otherwise, the significant decrease in the males number in these fields can be explained by the brain drain phenomena in Tunisia [32]. This is consistent with our data, showing more an increase of woman than a decrease in men in student population. Moreover, 10000 graduates and ICT sector trained people in Tunisia left the country during the last three years to work and live out of the country according to the Tunisian Engineers Order [33]. This is again rooted to the devaluation of the Tunisian dinar and the general economic crisis [34]. In this context, [35] confirm that life satisfaction and life-quality pressures promote women's and girls' engagement within many countries. Otherwise, departures are more possible for men, since Arab women generally adopt and assume family responsibilities which

can be the reason behind the positive imbalance in the Tunisian higher education institution.

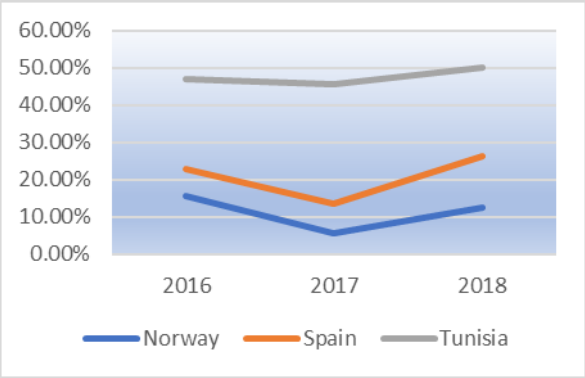

Figure 1: % of female students in ICT, by country and year

In sum and in the case of Tunisia, we see a good gender balance but a disconnection of GDI and GII indexes with this IT gender balance.

IV. General Discussion and Future Work

The underrepresentation of girls and women in science, technology, engineering, and mathematics (STEM) is a continual issue for policy makers and social scientists alike [35]. In this context, this paper presents an exploratory study on gender gap in computing studies comparing figures from three different countries: Norway, Spain and Tunisia.

Figure 1 clearly shows that the gender gap in computing studies is not narrowing significantly, independently from the country. However, there are some noticeable differences between the three countries.

In an almost perfect welfare environment along with maybe the most equalitarian society in the world, Norway presents just around 10-15% of women in computing. In the case of Spain, numbers are a bit higher, however, there is a loss in woman students' base in a scenario of relatively high unemployment rate especially for young workers. Regarding Tunisia, gender balance in the case of students is a fact and a remarkable achievement. However, the high number of women enrolled compared to the two other countries is also a consequence of the decrease of men enrolling in such studies due to brain drain the country is experimenting. With regard to faculty employees, the results point to a clear predominance of females and a higher concentration of women in computing teaching. On this path, it is important to mention that once Tunisian women scientists and engineers graduate, they don't come up against barriers to finding gainful employment and they overcome family bias against working in mixed-gender environments on the contrary of many other Arab countries according to the UNESCO Science Report [26]. However, it is also true that the overall scenario in Tunisia, according to GII and GDI indexes is far from being equal to women and is quite far from the figures presented by the other two countries.

Going back to the inferences by [16], we need to agree that, although we can draw some conclusions from our study, we cannot find a coherent explanation for gender imbalance in IT and we are unable to asseverate if interventions are addressing gender balance and that there are other factors that lead to bridge this gap.

In the case of Norway, leading equality rankings and interventions, we see a poor balance in IT. We can think also that unemployment is leading women to the field. This could be an explanation in the case of Tunisia. However, better but still weak employment numbers in Spain in this aspect are not leading us to this conclusion given the low and decreasing balance. Authors believe that beyond traditional numbers and rankings, there are other aspects to investigate and combine to shed some light. A recent paper [36], explores the connection of Hoefstede national cultures in the EU and gender misbalance in IT. According to the results of this study, there is not a clear connection between cultures and the number of women in IT. Authors also investigate unemployment rate and gender balance in IT in the EU zone with non-conclusive results. In the case of the work presented in this paper, authors believe that maybe the study of human values in the different countries could lead us to more conclusions in this specific aspect, given that particularities in the different countries appear.

However, we believe that the presence of women in IT studies is somehow connected to the employability in the cases in which this employability is crucial given the economic scenario. This could be the case of Tunisia, but also, connecting results with the ones provided in [36] the case of Bulgaria, Romania and Greece. These three countries are leading the rankings of women studying IT in the EU. In the case of Greece, where there is a big gap between women studying and working in IT (10.90% working while 29.23% are studying), opportunities to work abroad seem to be the reason behind this decision. In the case of Bulgaria and Romania, where this gap is also present, but more moderate, it seems that national IT industry is more capable to absorb this flow. If we take this approach to our study, we can see that in Tunisia the opportunities are inside the country and maybe these are the reasons behind this balance. However, it is also true that Sweden, with enrollment figures closer to the ones in Greece is presenting a quite different scenario with a quite low unemployment rate. Finally, Spain is, again, making the difference in this situation. With a high unemployment rate (at least for the EU zone) and a decreasing percentage of women in IT both in industry and in studies. Authors want to devote research to study the connection of values, employment opportunities, IT sector and gender balance. These values, together with the hope of family or government support could explain the lack of attractiveness of IT for female students in the case of Spaniards.

A second aspect to study is the probable connection of the possibilities to work abroad with the enrollment in IT studies both for men and women. This could be the case of Tunisia (and maybe to other countries like, for instance Greece). However, in the case of the African country, this aspect seems to be applicable just in the case of men. Nevertheless, this is also affecting the possibilities of women in work environments (due to the opportunities in the sector caused by the lack of resources rooted on men immigration) and maybe lead to higher enrolment of women in IT studies in the hope of an attractive employment in terms of security and overall conditions. This could also justify, for instance, the number of women working in IT in academia in the country. Authors are aimed to devote time to investigate this connection using immigration data in the field of IT and comparing it with the data presented in this paper.

Another aspect authors want to investigate is the behavior of immigrants in their country of adoption with regards to IT studies. It would be interesting to compare the career elections of immigrant students coming from foreign countries with the ones showed-up by their compatriots living in their country of origin. This could lead us to analyze how students are affected by educational systems features and structures along with environment pressures including values and culture.

One aspect to underline is the remarkable number of women in IT working as academics in the three countries. In the case of the European countries, figures are doubling women student population. In the case of Tunisian institution, almost 2 thirds of IT faculty are women, leading to a "positive" gender misbalance. However, authors cannot claim that this set of more balanced figures is a consequence of gender equality policies. One of the plausible explanations is the immigration of students and academics alike caused by crisis.

It is also needed to analyse the distribution of genders among figures (Professor, Associate Professor, Assistant Professor…) and its influence in the attraction of female students and vice versa. In the latter case, authors want to investigate if increases in female undergraduate enrolment in IT will increase overall female participation in all stages of academia as stated by [37] or as stated in [38], women's under-representation in STEM, including IT, is persistent and more a function of self-perception. In this sense, this hypothesis is backed up by the study of Leslie et al. [39] suggesting that women were least represented in fields that are believed to require innate talent. In the case of IT, mathematical talent is important and this is not traditionally associated with women.

In any case, it is needed to investigate the effectiveness of female role models in academia as a vehicle towards more gender balance among students. Authors underline the need to devote research to shed light on the quality of role models and not the quantity of them in both genders.

V. Conclusion

This paper explores the well-known phenomenon of gender gap in computing studies. Three universities from three different countries are the subjects of this study and data such as female students enrolled in one of the mandatory courses and female members of the faculties are collected. The newness of the approach taken in this study lies in the attempt at explaining the existent gender gap in computing studies through socio-economic variables such as GDP and unemployment rate.

Results show that the gender gap in computing studies is not narrowing significantly. Interestingly, data presented in this paper shows that the variable female students in computing is negatively correlated with GDP and positively correlated with unemployment rate. In fact, Tunisia showed the highest results in terms of female participation in computing while having a lower GDP and higher unemployment rate compared to the other countries. Despite this observation, authors believe that these results are complex to interpret and other factors such as immigration, opportunities to work abroad, brain drain phenomenon and effectiveness of female role models in academia need to be considered.

Within the scope of narrowing gender gap and regardless of country, culture and social and religious backgrounds, authors want also to propose a plan of actions including several recommendations such as highlighting the vital role of geographic and intergenerational alliances in narrowing gender gap, strengthening the commitment of policy-makers and the mobilisation of partnerships for gender equality, sharing best practices and experiences, both within and across sectors, policy areas and regions and strengthening visibility of female role models.

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