POLITECNICO DI MILANO

PhD in MODELLI E METODI MATEMATICI PER L'INGEGNERIA / MATHEMATICAL MODELS AND METHODS IN ENGINEERING - 41st cycle

Number of scholarship offered	6
Department	DIPARTIMENTO DI MATEMATICA

Description of the PhD Programme

POLITECNICO DI MILANO

PhD in MODELLI E METODI MATEMATICI PER L'INGEGNERIA / MATHEMATICAL MODELS AND METHODS IN ENGINEERING - 41st cycle

OPEN SUBJECT Research Field: MATHEMATICAL MODELS AND METHODS IN ENGINEERING

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	All candidates interested in developing their research in one of the areas of interest of the Department of Mathematics (see http://www.mate.polimi.it) are invited to apply for the grants in this area. The candidates will choose their specific research topic when the admission procedure is completed.
Methods and techniques that will be developed and used to carry out the research	The PhD program aims at training young researchers by providing them with a strong mathematical background and with the ability to apply their knowledge to the solution of problems that may arise in various areas of science, technology, industry, finance, management, whenever advanced methods are required in analysis, design, planning, decision and control activities.
Educational objectives	The PhD students carry their research in the development of new mathematical methods and/or in the implementation and improvement of advanced techniques in connection with specific contexts and applications. Further information can be obtained by consulting the dedicated website http://www.mate.polimi.it/dottorato

Job opportunities	Job opportunities are in italian or international universities, companies and research agencies which are leaders in their respective fields.
Composition of the research group	28 Full Professors 52 Associated Professors 44 Assistant Professors 50 PhD Students
Name of the research directors	Michele Correggi

Contacts
Program Chairman: Professor Michele Correggi e-mail: michele.correggi@polimi.it phone:+390223994523 https://sites.google.com/view/michele-correggi

Additional support - Financial aid per PhD student per year (gross amount)			
	1st year	**2nd year**	**3rd year**
Housing - Foreign Students	1500.0 € per student	0.0 € per student	0.0 € per student
	max number of financial aid available: 1, given in order of merit ..		
Housing - Out-of-town residents	--		

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
Educational activities (purchase of study books and material, funding for participation to courses, summer schools, workshops and conferences): financial aid per PhD student per year 1st year: max 1.902,40 euros per student 2nd year: max 1.902,40euros per student 3rd year: max 1.902,40 euros per student. The PhD students are encouraged to take part in activities related to teaching, within the limits allowed by the regulations.1 individual PC per student +several shared PC. Access to one cluster with 32 processors and 384 GB RAM, and to several multi-processor servers.

POLITECNICO DI MILANO

PhD in MODELLI E METODI MATEMATICI PER L'INGEGNERIA / MATHEMATICAL MODELS AND METHODS IN ENGINEERING - 41st cycle

THEMATIC Research Field: OPERATOR LEARNING FOR COUPLED PROBLEMS WITH APPLICATION TO SUBSURFACE MODELING

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	Operator learning is a novel and highly effective technique for approximating differential problems using high-fidelity data or high-fidelity approximations. It has proven to be particularly efficient for solving both forward and inverse problems. The aim of this thesis is to explore the use of operator learning to develop upscaled differential models for subsurface flow in the presence of significant heterogeneities and fracture networks.
Methods and techniques that will be developed and used to carry out the research	Operator learning is an emerging paradigm aimed at approximating mappings between infinite-dimensional spaces, such as those associated with partial differential equations (PDEs). By leveraging machine learning, particularly neural operator architectures, operator learning provides a supervised framework to address computational challenges in scientific and engineering problems where traditional approximation methods struggle due to high dimensionality or complexity (N. Boullè A. Townsend, A Mathematical guide to operattor learning, Handbook of Numerical Analysis, 25:83-125, 2024, Andrew M. Stuart, Nicholas H. Nelsen. Operator Learning Using Random Features: A Tool for Scientific Computing. SIAM Review, 66(3):737–776, 2024).The objective of this thesis project is to study and analyse possible estensions of operator learning architectures to time-dependent coupled problems, improve sample

	efficiency and integrate operator learning with physical models to ensure interpretability and reliability. The target application is modeling subsurface problems to enable more sustainable exploitation of subsurface resources and CO2 sequestration. The heterogeneity of the subsoil and the presence of fractures at varying length scales make the study of underground flow highly complex and computationally expensive. Standard upscaling techniques, whether analytical or numerical, often fail to produce reliable and cost-effective models. However, well-established high-fidelity models are available, which can be used to leverage numerical high-fidelity results for constructing an upscaled differential model through the novel operator learning architectures analysed in this study.
Educational objectives	The student will get acquainted with state of the art techniques for simulation of complex problems and develop skills to critically analyse operator learning architectures and apply them to physically relevant contexts. He will acquire skill in scientific computing, machine learning, and numerical approximation of partial differential problems.
Job opportunities	The profile proposed here are broadly relevant for a range of employers including (but not limited to): renewable energy providers, research centers, consulting or high-tech companies. The skill acquired are also propaedeutic for an academic career.
Composition of the research group	2 Full Professors 2 Associated Professors 1 Assistant Professors 0 PhD Students
Name of the research directors	Proff. Luca Formaggia e Paolo Zunino

Contacts
luca.formaggia@polimi.it; paolo.zunino@polimi.it

Additional support - Financial aid per PhD student per year (gross amount)			
Housing - Foreign Students	**1st year**	**2nd year**	**3rd year**

	1500.0 € per student	0.0 € per student	0.0 € per student
	max number of financial aid available: 1, given in order of merit ..		
Housing - Out-of-town residents	--		

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information

Educational activities (purchase of study books and material, funding for participation to courses, summer schools, workshops and conferences): financial aid per PhD student per year
1st year: max 1.902,40 euros per student
2nd year: max 1.902,40euros per student
3rd year: max 1.902,40 euros per student.

The PhD students are encouraged to take part in activities related to teaching, within the limits allowed by the regulations.
1 individual PC per student +several shared PC, as well as access to Departmental high performance cluster and the computer resources available through the CINECA consortium.

POLITECNICO DI MILANO

PhD in MODELLI E METODI MATEMATICI PER L'INGEGNERIA / MATHEMATICAL MODELS AND METHODS IN ENGINEERING - 41st cycle

THEMATIC Research Field: SPATIAL ANALYSIS OF INEQUALITIES IN EARLY CHILDHOOD EDUCATION AND THEIR IMPACT ON WOMEN'S LABOUR MARKET PARTICIPATION

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	This project aims at investigating the availability of Early Childhood Education and Care (ECEC) services in Italy at the provincial level and their impact on women's participation in the labour market. The study will explore the spatial variability of these two variables and assess their statistical relationship. ECEC attendance is considered beneficial for two main reasons [1]. First, it tackles one of the impediments to women's work: the care of young children. Secondly, ECEC attendance improves children's social and cognitive development, with several studies pointing at the benefits obtained in later life by attending ECEC in the early years. ECEC has gained significant attention and investment in recent decades, driven by OECD recommendations and EU commitments. However, Italy lags behind in achieving ECEC attendance targets compared to European averages. To address this gap, the Italian government has planned to invest €4.6 billion from the PNRR to enhance ECEC provision. However, no evaluation has been proposed so far regarding the effectiveness of this plan and its capacity to tackle the need for ECEC where it is most needed. The literature has shown that ECEC availability varies across regions within a country in Europe and overseas, with significant disparities in accessibility, often influenced by socioeconomic factors. This research will account for territorial variability by employing clustering techniques to

	group provinces with similar patterns in ECEC availability and women’s workforce participation. This approach will help identify territorial inequalities and assess policy impact. As a second scope, the PhD candidate will collaborate in the comparison of the provision of ECEC service in two cities, Milan and Barcelona, focusing on the construction of a dataset on ECEC in both cities. The PhD candidate will also play an active role in disseminating the findings to civil society and local and national policymakers.[1] Naumann, I. (2012). Childcare Politics in the ‘New’ Welfare State.[2] Andreella, A., Aliverti, E., Caldura, F., &Campostrini, S. (2024). Spatial clusters for demand and supply of childcare services in Italy. Socio-Economic Planning Sciences.[3] Mozdzen, A., Cremaschi, A., Cadonna, A., Guglielmi, A., &Kastner, G. (2022). Bayesian modeling and clustering for spatio-temporal areal data: an application to Italian unemployment. Spatial Statistics.
Methods and techniques that will be developed and used to carry out the research	The research will begin with a detailed analysis of the territorial distribution of ECEC services and women’s employment rates at the provincial level in Italy, considering all the possible variables that constrain women’s labour market participation. The dataset will be made of territorial indicators for development policies of the 107 Italian provinces, such as women’s employment, ECEC take-up rates, at-risk-of-poverty rates, and other useful socioeconomic indicators, over the past decade. As in [2], this dataset will be integrated with additional data, at the province level, from the ISTAT "Survey of Child Care and Early Childhood Supplementary Services" and the ISTAT permanent census, to better understand the demand and supply of ECEC in Italy.The PhD candidate will first review distance-based clustering methods for areal data and areal data varying in time. Then, the candidate will focus on Bayesian models for clustering areal data or areal time series, as, for instance, in [3]. However, new recent Bayesian nonparametric models can be considered, as those including the random partition of the Italian provinces as the main parameter of interest. The theory of random partitions is a key ingredient for devising models that can effectively address

	inference on the clustering structure featured by the data. However, the associated computational schemes might yield non-scalable algorithms, with respect to the sample size, for computing the posterior. To define a new class of priors for the areal units which take into account their spatial connotation, the project should consider priors encouraging data in neighbouring provinces to be more correlated than those far apart. Further research will investigate models designed for spatio-temporal areal data to address computational challenges associated with large datasets.By leveraging advanced statistical techniques, this study aims to provide a robust framework for evaluating ECEC accessibility and its broader socioeconomic implications.
Educational objectives	The PhD student will have the opportunity to increase his/her abilities as a statistician or a data scientist, with strong expertise in statistical learning for spatial data. In particular, the student will study, develop and apply innovative statistical techniques for spatial analysis, time series and clustering, in order to identify spatial or spatio-temporal variability of the effect of ECEC rate on the women‘s labour force in the Italian provinces.
Job opportunities	The program will allow the student to find a job as a statistician or a data scientist. Moreover, the expertise in spatio-temporal statistics is nowadays a key methodological factor in many applicative industrial fields such as 5G/6G telecom networks, IoT applications (smartcity, public utility), manufacturing and logistics, climatic studies, and for all new technologies allowing for “data everywhere and everytime’’.
Composition of the research group	1 Full Professors 1 Associated Professors 0 Assistant Professors 4 PhD Students
Name of the research directors	Prof.ssa Alessandra Gugielmi

Contacts
alessandra.guglielmi@polimi.it

Additional support - Financial aid per PhD student per year (gross amount)			
	1st year	**2nd year**	**3rd year**
Housing - Foreign Students	1500.0 € per student	0.0 € per student	0.0 € per student
	max number of financial aid available: 1, given in order of merit ..		
Housing - Out-of-town residents	--		

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

Stage and period abroad	
Institution or company where the candidate will spend the period abroad (name and brief description)	
By number of months abroad	0

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information

Educational activities (purchase of study books and material, funding for participation to courses, summer schools, workshops and conferences): financial aid per PhD student per year
1st year: max 1.902,40 euros
2nd year: max 1.902,40 euros
3rd year: max 1.902,40 euros

The PhD students are encouraged to take part in activities related to teaching, within the limits allowed by the regulations.1 individual PC per student +several shared PC. Access to one cluster with 32 processors and 384 GB RAM, and to several multi-processor servers.

Study and research period abroad: from 6 to 12 months at the Institute of Government and Public Policy (IGOP) at the Universitat Autònoma de Barcelona, professor Lara Maestripieri. Further funding is available to partially cover the expenses in Barcelona.

The PhD project will promote the use of research results and guarantee the protection of intellectual property, ensuring open access to the public to research results and related data, in the shortest time and with the least possible limitations, according to the principles "Open science" and "FAIR Date".

This PhD project is within the activities of a project funded by Inequalities Research 2024, Fondazione Cariplo, Rif. 2024-1373, entitled *Where to grow a child? Spatial inequalities in ECEC and its impact on women's labour market participation* (#GROW).